THE DEVELOPMENT OF BRITISH HEATHLANDS AND THEIR SOILS

BY

G. W. DIMBLEBY

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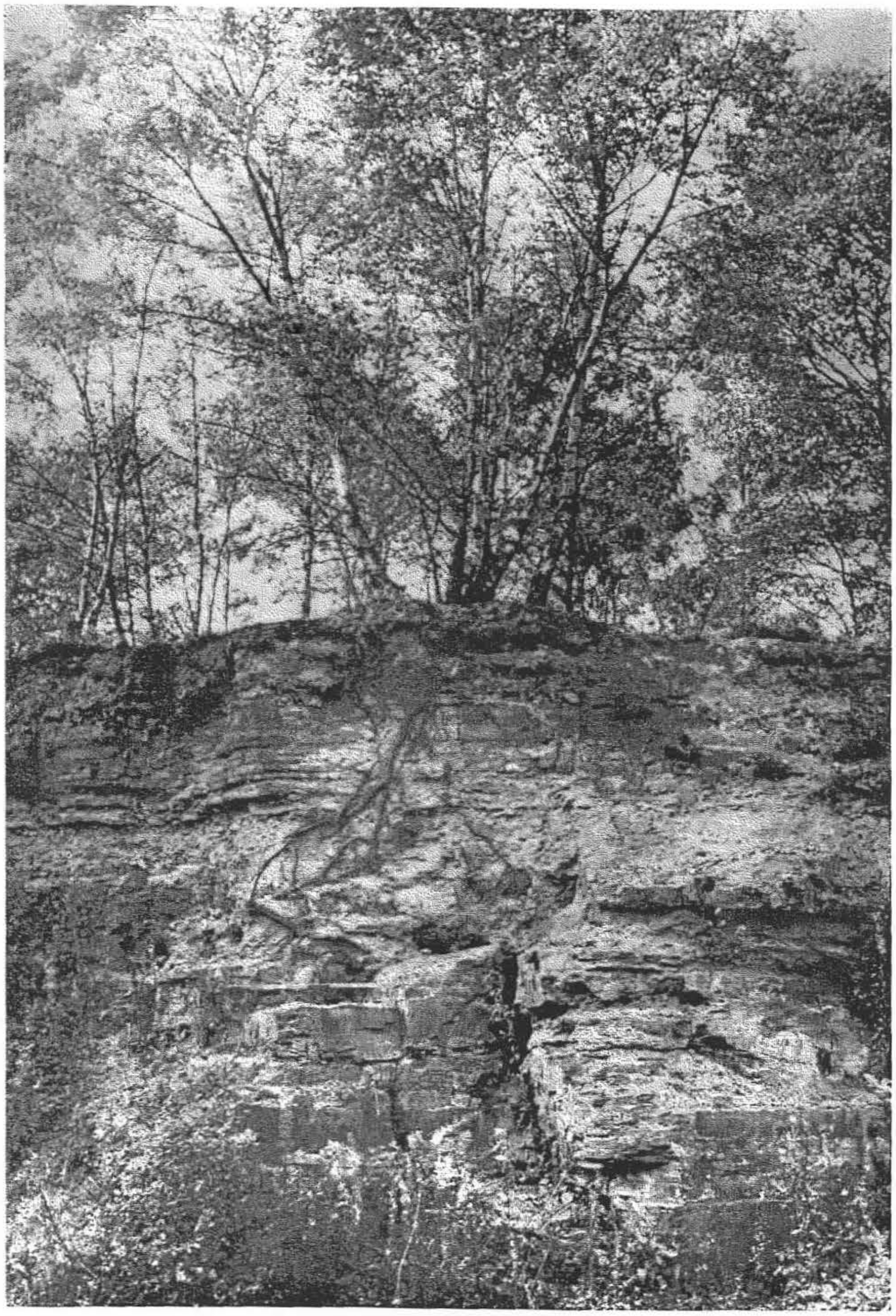

Quarry face exposing root system of coppiced birch growing on a heathland humus podzol.
The horizontal scale marks a geological change from acid sandstone above to limestone below.
Yearsley Moor, North Riding, Yorkshire

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PREFACE

THIS Memoir is an attempt to co-ordinate the results of observations on a large number of sites in a way which is not possible in a series of shorter papers. Such papers have already been published on some of the sites—especially the archaeological ones—but much of the material is published for the first time. The text is presented in two parts: first comes the comparative study of the sites, particularly in relation to modern thought on vegetational change and soil genesis, and this is followed by more detailed description and interpretation of each site.

I cannot thank by name all those archaeologists, soil scientists, botanists, and foresters with whom I have had valuable discussions, and whose help, often in the field, has been much appreciated. I must acknowledge, however, the kindness of Dr. H. Godwin, F.R.S., who has so readily given me help with the identification of pollen specimens, and of Dr. L. Chalk, to whom I have turned when in difficulty over the identification of charcoals. I also wish to express my great indebtedness to Professor W. H. Pearsall, F.R.S., and to Mr. D. Mackney of the Soil Survey of England and Wales. Their comments and criticisms—the one particularly in the ecological field and the other in pedology—have been invaluable. If they fail to recognize this as the text they originally read, this is a measure of the extent of their constructive help. The reproduction of colour photographs has been made possible by a grant from the Royal Society. No other form of illustration effectively portrays soil profiles, so I am deeply grateful to the Society for its generosity. Lastly, my thanks and appreciation must go to Mr. P. Porter who has been my right-hand man in all phases of this work; the photographic records are entirely his work. The diagrams have been expertly drawn by Mr. J. Shaw.

The pollen analyses of so many sites resulted in a mass of data which has not been included for reasons of economy. These data are not necessary to an understanding of the text, but those who wish to see them may obtain a set (free of charge) from The Librarian, Department of Forestry, Oxford University.

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Oxford
October 1960

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Plates I to VIII (in colour) are placed at the end.

I. INTRODUCTION

It has been taken as a working hypothesis that the state of the acid soils in Britain today is not the result only of the present site factors, but equally of those that have operated in the past. It is almost a truism to say that soil development depends upon the five factors: climate, parent material, topography, vegetation, and time; but it is frequently and conveniently assumed that these factors remain more or less constant or that any changes that may have taken place have not been of a type likely to affect the soil processes. It is often not realized that, for instance, vegetation changes combined with time may cause a major change in these processes. The ecologist is accustomed to seeing such changes taking place in the environment today, and there is plenty of evidence that they have taken place in the past, especially where man has been active.

It has already been shown that land which is now heathland was sometimes quite different in soil and vegetation in prehistoric times; in fact, that its present condition is secondary, the result of anthropogenic influences. In particular it has been shown in such cases that the podzol soil may be secondary to the brown forest soil.

This conclusion probably applies to extensive areas of western Europe where early man had once been active, but it does not follow that all podzols are artificially induced; we do not even know whether all heathland podzols are secondary. Indeed much more needs to be known about the process of soil degradation, and as some contribution towards this the present work has been carried out to elucidate further the environmental factors which lead to active podzolization. In particular, a study of those factors, introduced by early man, which can be linked with the intensification (if not the onset) of podzolization, may help to resolve the conflicting views on the process which some see as degradation and others as normal soil maturing. This is not just a matter of theoretical importance; land with such soils is now being intensively used for forestry, a long-term practice which is dependent for its success on the continuing fertility of the soils. We must know whether the higher fertility of the past has been irretrievably lost, and whether the present fertility, such as it is, is going the same way.

II. METHODS

There are two approaches to this type of problem, the intensive and the extensive. Is it better to examine a few sites in full detail and be left with the suspicion that the sites might not have been quite representative, or should a wide range of sites be examined in scanty detail so that no one of them is fully documented? In this case the latter course was selected because the principal instrument of investigation, pollen analysis, had not previously been used in this way and its application to a wide range of sites was of intrinsic, fundamental interest. This method itself was time-consuming enough, and to have combined

it with chemical and mechanical analyses would have rendered the project stillborn. It seemed more logical to carry out more detailed investigations later on those sites that appear critical from the initial survey.

(i) *Pollen analysis.* The technique used and the method of interpretation adopted are those described elsewhere (33, 34). A number of sites used as illustrations in those papers are dealt with here in their full ecological and pedological context.

(ii) *Charcoal analysis.* Charcoal is of frequent occurrence in many soils and is particularly associated with archaeological sites. Only rarely can it be said with certainty that it originated from vegetation *in situ* (e.g. when found in root channels), so its value for determining the vegetation at any given time is limited. The contradictory views expressed by Salisbury and Jane (94) and Godwin and Tansley (54) underline the difficulty of drawing conclusions from charcoal alone, but it can form a useful adjunct to pollen analysis; conversely, pollen analysis can show that charcoal did not originate from the site itself (e.g. Chick's Hill Barrow (2)).

Identification of the charcoal has been carried out by examining fresh fractures through a low-power binocular microscope ($\times 40$) using diffuse surface illumination. In cases where finer detail must be recognized, especially on longitudinal sections, a normal binocular research microscope, simply adapted for surface illumination of the object, has proved satisfactory. The problem of setting irregular pieces of fragile charcoal at the correct angle was overcome by mounting them on plasticine so that they could be adjusted easily without major disturbance.

By these methods it has proved possible to obtain satisfactory identification even of small fragments of charcoal, though the lower limit of size clearly varies with the type of wood structure. In all cases comparison was made with charcoal prepared from identified material. In cases of difficulty it has been a great assistance to have the Imperial Forestry Institute wood specimen collection (including microscopical slides) available for reference.

(iii) *Soil records.* Experience has shown the great difficulty of conveying a visual picture of a soil profile in words alone, and the use of colour references, such as the Munsell Color Charts, while of value to anyone interested in detail, does not assist the general reader. Black-and-white photographs can add to verbal descriptions, but they can be very misleading. For instance, in a podzol there is usually no distinction in tone between the bleached layer and the yellow subsoil.

For these reasons, and in spite of the inevitable difficulties of reproduction, records throughout this work have been kept primarily in the form of colour photographs, using only such additional notes as are necessary to define characters such as texture which are not registered in a photograph. This not only gives an immediate picture of the soil but saves a great deal of tedious and often repetitive description.

In addition, these records have been augmented by adhesive tape profiles (see below).

(iv) *Adhesive tape (A/T) profiles.* In the field one is frequently in doubt about the degree of leaching of humus-stained horizons, in which the humus may conceal intensive leaching; conversely, what appears to be an intensively leached

horizon may prove to have a certain amount of iron left in it. Such limitations in direct observation are overcome by igniting the soil, when organic matter is burned away and the formation of sesquioxides intensifies the colour due to iron. No attempt has been made to estimate iron quantitatively by this method, though the work of van Diepen (24) suggests that this may be possible; Pearsall (private correspondence) has also made some progress in this direction.

Ignition has been adopted as standard practice in all sampling, and the ignited soils have been permanently mounted alongside the unburnt soils. This has been done most conveniently upon transparent waterproof adhesive tape (which does not move with changes in atmosphere humidity), mounted on card, so that each soil record can be kept in a loose-leaf file. In many cases the profiles do not extend right down to the subsoil as they should, the reason being that these sites were originally sampled only for pollen analysis, which does not call for deep sampling. The value of the A/T profiles only appeared subsequently and use had to be made of whatever samples existed.

The technique is briefly as follows: each sample taken for pollen analysis was oven-dried, powdered, and passed through a 1-mm. sieve. A gramme or two of this powder was taken and ignited either in a crucible over a bunsen flame or in a muffle furnace (there is virtually no difference in the resulting colour) until no further colour change occurred. When cool this ignited soil was dusted on to the sticky side of a strip of adhesive tape, 1-cm. length for each 1-in. sample, so that a succession of adjacent samples was built up, representing the sequence in the soil profile. By leaving a short length of adhesive uncovered at each end of the profile, the tape could be reversed and fixed on the card, then firmly set all round with plastic binding tape. The samples are thus viewed through the tape. For comparison a similar profile was prepared from the unignited soil and mounted alongside (see Plates IV and VI).

These profiles have proved very useful, not only as a record, but in providing information which could not be detected in the field. Just how permanent they are remains to be seen. Some are now over three years old, and show little sign of deterioration except where the ignited material is solely ashed organic matter. It does seem important, however, that a waterproof tape (not the ordinary cellulose tape) is used and that the gum should be completely covered with soil, leaving no gaps. The gum of some makes appears to be more liable to fungal infection than others, but infection can be eliminated by painting the finished tape with a 1 per cent. alcoholic solution of mercuric chloride.

III. SELECTION OF SITES

THIS work originally started as an intensive study of the upland heaths of the Tabular Hills in north-east Yorkshire, which were offering severe afforestation problems to the Forestry Commission. Attention had been directed particularly to the soil condition, and it soon became apparent that the present state of the soil was the result of age-long mismanagement and neglect (28, 31). As opportunity offered, further work on archaeological sites was continued in this area, but in addition inquiries were extended to provide comparative data from other

areas. To provide comparison with lowland heaths, sites in the New Forest were studied, and for comparison with conditions at even higher altitudes, areas of Callunetum on the Cleveland watershed above the 1,200-ft. contour were examined. The common factor to all sites at that stage was the existence today of Callunetum on shallow (less than 6 in.) peat or raw humus; deeper peats, even if they carried *Calluna*, were excluded. This criterion took no account of the nature of the mineral soil, except in so far as it provided conditions suitable for *Calluna* to become dominant. Consequently, the soil materials studied range from sands and gravels to heavy clays, so that pedologically the different soils may not be closely comparable. Biologically and ecologically, however, there is no wide divergence today, whatever may have been the condition in the past.

The selection of archaeological sites has been largely beyond the control of the writer. Usually complete excavation of a barrow or earthwork was necessary to establish dating, so the ecological investigations were normally secondary to the archaeological work; thus there was no choice of site. In the course of time attention was drawn to excavations in other areas, not always on heathland, and this accounts for the scattering of sites beyond the areas mentioned. In a number of cases these sites proved to be of outstanding interest and value.

It will be seen, therefore, that no attempt was made to make a representative study of the acid soils of Britain, though the work did extend beyond the heathland type of vegetation with which it originally started. The geographical distribution of sites is shown on the maps comprising Fig. 1.

IV. SOIL PROFILE DEVELOPMENT

WITHIN the sites investigated there is a considerable range of soil types occurring today beneath Callunetum; humus–iron podzols, thin iron-pan soils, gley podzols, and peaty gleys. The last category, in this investigation, is represented only by heavy parent material at high altitude (e.g. Ralph Cross); the humus–iron podzols are commonly found on the lowland heaths, and the thin iron-pan soils on the upland heaths and high-altitude 'moors' of the Cleveland and Tabular Hills. A common feature of all four soil types is a bleached A_2 horizon overlain by *Calluna* raw humus, but the lower horizons may be widely different.

A further type, seen especially in some woodland soils, is the micropodzol, a miniature profile 2–3 in. deep, which is assumed to be essentially recent. Since no intermediates have been seen between this and the deeper profiles, little attention has been paid to it. Nor has much weight been placed upon the degree of humic staining of the A_2 horizon, which seems to be very variable and inconsistent.

In a few sites soils have been found which show little or no bleaching (apart from a micropodzol in some cases), but none of these are under heather today. Indeed, earlier work in the New Forest (36) suggested that such soils never have been under heather. These unbleached—or only slightly bleached—soils would seem to fit into the *sols bruns acides* category of Duchaufour (42) or a slightly degraded version of it (e.g. Burley Oak and Matley Wood). Though they are nowhere common in areas which are heathland today, they have been found both

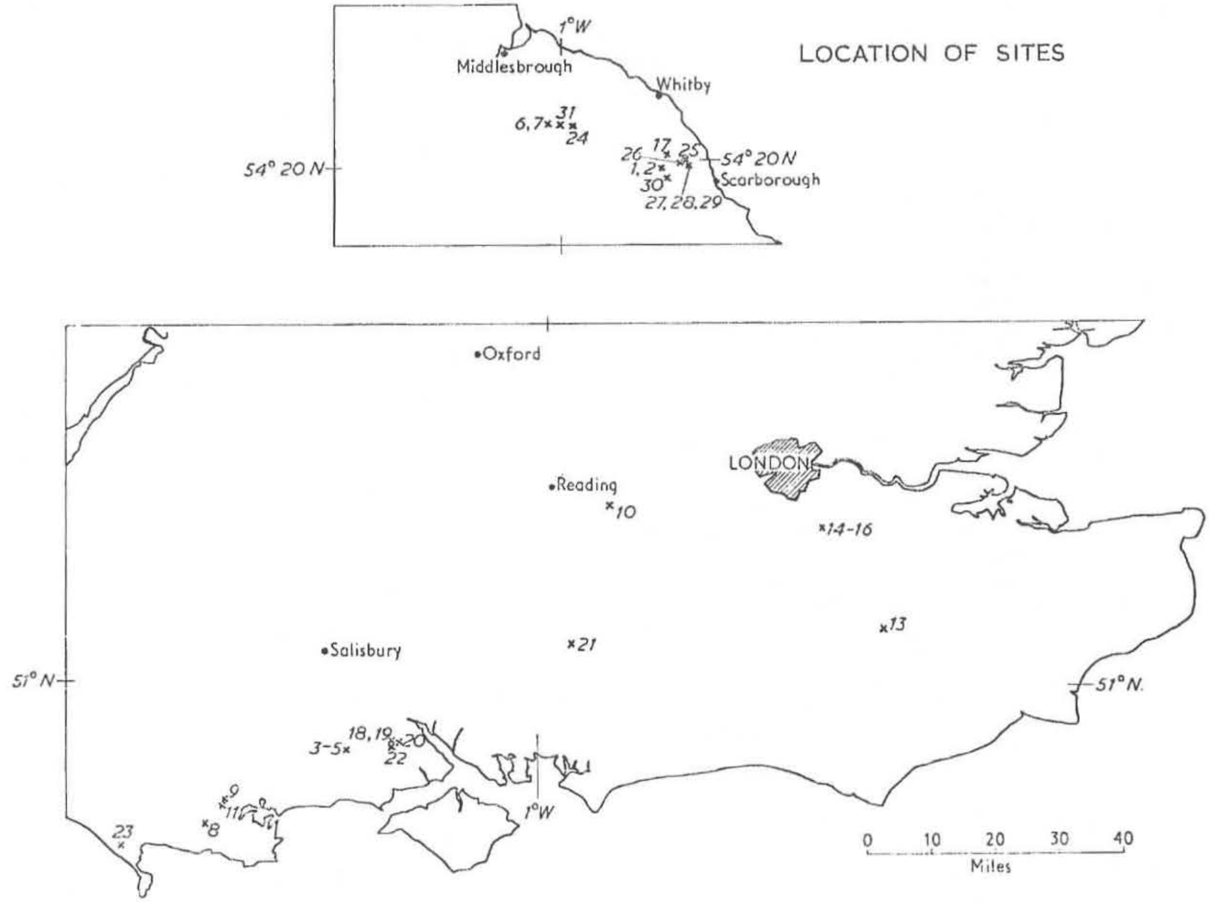


FIG. 1. Maps showing the location of sites. Two sites, No. 12, Goodland (Co. Antrim) and No. 32, Winter Hill Barrow (Lancs.), are not covered by these maps.

in the New Forest and in the Tabular Hills. It has already been suggested that their persistence may be due to avoidance of heath cover—in fact, due to an historical accident. The A/T ignition profiles show that in such cases there may be gradual increase of iron with depth and some accumulation below, but the A_2 horizon is not clearly separated from the B below. In this they contrast with the sharply differentiated morphology of the adjacent heath soils.

It has been suggested (30, 36) that such soils represent a steady state under forest conditions, from which the present heath soils have been developed as a consequence of deforestation and exploitation. Clear exceptions to this generalization will be produced in this paper (e.g. Keston Common) but it remains broadly true in most cases. It is remarkable that intermediates are very rare between these *sols bruns acides* and the degraded heath soils.

It was in the hope of learning something about the intermediate stages that attention was directed to the soils buried beneath prehistoric earthworks. The potentialities of heathland barrows as a source of information about the history of heathland were recognized as long ago as 1876, when Emeis (47) drew attention to and illustrated the variety of soils beneath barrows, as well as on the mounds themselves. He rightly concluded that many heathlands were in existence at the time barrows were built, but from this—excusably underestimating the influence of man on his environment—he assumed that the heath and its soil was a natural development. One of the figures shown by Emeis portrays a barrow with an unleached soil beneath it, and this condition has become increasingly recognized as characteristic of the earlier barrows. Van Giffen and his successor, Waterbolk (116), found as a general rule that on Dutch heaths there was no podzol below the Neolithic structures, whereas a podzol was usual under Bronze Age mounds. More recently, exceptions to this rule have been discovered. Modderman (73) found a podzol beneath a Neolithic barrow, which he assumed (without pollen analysis) to be a forest podzol and not a heath soil, since the sods of which the mound was built were different from true heather sods; in the absence of botanical confirmation this hypothesis can only be regarded as tentative. Waterbolk (117), however, has since described two podzols beneath Neolithic mounds and shown by pollen analysis that they were associated with heath, a fact which is difficult to reconcile with commonly accepted theories about the spread of heath as a consequence of climatic deterioration (e.g. van Zeist, 125).

In north-west Germany and Denmark, according to Schwantes (98), several workers have recognized bleached horizons or *ortstein* beneath tumuli of the Single Grave culture (Neolithic), suggesting that heaths were extensive there at that time, and, moreover, had been in existence long enough to allow a heath podzol to mature. Schwantes discusses the relationships between soil types and vegetation at some length, and stresses the importance of soils in determining environmental conditions in prehistoric times.

On the whole, however, archaeologists have been slow to appreciate the significance of buried soils, though observations have been made from time to time. For instance, Curwen (19) reports observations made by Jensen in Denmark on soils buried under lynchets of pre-Roman Iron Age. The heath conditions, in this case, did not exist at that time, and it was concluded that the early farmers chose the zone of overlap between heath and forest for their cultivation (see also

p. 32). In recent years in Britain soils reports have become a more frequent feature of excavation accounts, often combined with botanical analyses (e.g. Case, 11). Yet it is more frequently the soil scientist who has been inquisitive about what the earthworks could reveal. For instance, Dudal (44) and Veenenbos (114) have both examined buried soils as a means of elucidating the genetical connexions between soil types.

For such purposes, however, much more valuable results may be expected from comparative work than from individual cases, and little or nothing in this line has been attempted anywhere. As wide a range of age as possible should be studied in this way, and it is therefore unfortunate that so far it has not been possible to examine a Neolithic buried soil in Britain on land which now carries heath. The Neolithic people apparently avoided such land and Neolithic earthworks are exceedingly rare in these areas in Britain, in contrast to Denmark or Holland.

For the purpose of clarity in presenting the observations, and without implying thereby that there are fundamental differences between them, the sites will be described as three distinct groups: the upland heaths, the lowland heaths, and the high-level 'moor' sites.

The upland heaths of the Tabular Hills today characteristically have a thin iron-pan soil, the iron-pan being well developed and exceedingly indurated. The soils beneath the Bronze Age barrows show remarkable contrasts. Brief reference was made in an earlier paper (31) to an unleached soil beneath a barrow within the Thieves' Dykes on Suffield Moor, where the podzol went over the mound and not underneath it. A similar condition was examined in more detail beneath Bickley Moor Barrow; there was no bleached A_2 horizon, though iron movement from the top 4–6 in. could be detected visually and there was some accumulation in a diffuse B horizon. There was no trace of an iron-pan, but a thin iron-pan podzol ran over the surface of the mound (Plates III, 1 and IV, 1). Springwood Barrow (31) showed a very similar condition in one section, but in another profile under the same mound there was distinct but incomplete bleaching of the top 3 in. of the buried soil (Plate IV, 2 and 3). Again no trace of iron-pan was to be seen. Finally in this sequence comes the Reasty Top Barrow, archaeologically of the same date as Springwood (Urn phase of the Middle Bronze Age), which showed 5 in. of fairly intensive bleaching, and traces of a thin iron-pan were beginning to show at 6 in. (Plate IV, 4). This pan was not indurated and contrasted strongly with the pan under heath outside the barrow. In other respects, however, the soil profile was remarkably similar to the present heath soil. Since all these barrows are of essentially the same period (Bickley Moor Barrow has not been dated but is a large round barrow presumably of the Bronze Age) it seems fairly clear that within the Bronze Age—perhaps within the Middle Bronze Age—rapid soil development took place, producing the thin iron-pan podzol from what had been an unbleached soil with only slight iron-removal and a diffuse B_{Fe} horizon. Since the Bronze Age the solum has not altered in dimension, but the differentiation between horizons has been intensified and in particular the iron-pan has become strongly indurated.

In the southern heaths the characteristic heath soil today is the humus–iron podzol, or, if there is subsoil impedance, the humus–gley podzol. The archaeological sites available for comparison here were not so closely related either

geographically or geologically to the heaths as were those in the Tabular Hills, but they show certain well-defined trends. The soil beneath Chick's Hill Barrow was a distinct humus–iron podzol, though the removal of iron from the A_2—as indicated by the A/T ignition profile—was not complete. The profile was a relatively deep one. The humus accumulation in the B horizon was diffuse and though this soil may fairly be described as a humus–iron podzol, it was much less intensively developed than the characteristic heath soils of today (Plate III, 2).

Similarly, the soil buried beneath the barrow at Burley, though itself showing clear horizon differentiation, showed less development, particularly in the B horizons, than the present soil of the area on Burley Heath (Plate VII, 3 and 4). This site has a shallow (1 ft.) layer of sand overlying a heavier subsoil, which gives rise to gley conditions below. Both the present soil and the prehistoric soil show well-bleached A_2 horizons, but the contrast comes in the B; in the prehistoric soil there is the merest trace of humic accumulation and none of iron, but in the modern soil there is a strongly developed B_H horizon, though iron accumulation is not strongly marked.

The third archaeological site investigated in the lowland heath area was the medieval earthwork at Lyndhurst, known as The Ridge. This is a long ditch and bank built in 1299 to enclose a royal deer park (107). The buried soil beneath the bank is a humus–iron podzol indistinguishable from the present-day soil of the surrounding heath (White Moor), in which there is very strong development of the B horizon and particularly the B_H (Plate VIII, 1–3).

The developmental sequence as represented by these sites does not begin with such undeveloped profiles as were seen on the Tabular Hills. The two barrows studied were Late Bronze Age compared with the Middle Bronze Age of the Yorkshire area, so one might expect their buried soils to show greater development. However, Cornwall (in Case, 11) has described a podzol beneath an early barrow in the same region: it is interesting that this soil, though a podzol, also showed an absence of B horizon, which led Cornwall to postulate that iron accumulation at the water-table at 10 ft. depth was due to this podzolization. However, such accumulation may be found even in calcareous unpodzolized gravels (Plate I, 2). Though there is no evidence from the archaeological sites studied in this area that the soils were originally unleached as in Yorkshire, nevertheless unleached soils are found in the area today, so it is not impossible to regard these buried soils as derivatives from the *sol brun acide* or a similar type. (This point will be returned to later.)

It is quite clear from the soil beneath The Ridge that morphological differentiation was complete by A.D. 1300 and may have been so for some centuries earlier—one cannot tell. Unfortunately no earthworks which might close the gap of 2,000 years between the prehistoric and medieval sites have yet been located or excavated.

The third group of sites is on the watershed of the Cleveland Hills, at altitudes of 1,200–1,400 ft. O.D. The present soils are mainly thin iron-pan soils or peaty gleys, their occurrence being determined largely by texture and this in turn being determined by the somewhat complex geology of the area. At Ralph Cross, for example, within a small apparently uniform area of Callunetum the soil type changes from the peaty gley on heavy clay to the thin iron-pan soil on more loamy material.

The only buried soils examined have been from the two barrows 1A and 4D in the Burton Howes group. The former showed a clear thin iron-pan soil (Plate V, 1), and the latter a peaty gley (Plate III, 4), again clearly a reflection of textural difference. It is interesting that both mounds were composed of turves mostly cut from a peaty gley closely similar to that under mound 4D, but the iron-rich nature of some parts of the mounds, e.g. the 4–8-in. zone of the present surface of 1A, suggests that unleached topsoil may have occurred in the neighbourhood. Both buried soils were shown by pollen analysis to be truncated, though for mound 4D comparison with the turves of which it was composed suggests that not a great depth of material had been removed. Though in a different region, the barrow on Winter Hill (Lancashire) showed close parallels with these two, and may usefully be included here. It also was of turf construction; its buried soil was a thin iron-pan soil (Plate III, 3) and it also had been truncated at some time, though not immediately prior to the construction of the barrow.

It will be shown later that these high-level sites were all wooded at one time and this fact is important in considering the soil types. It is difficult to believe that thin iron-pan soils or peaty gleys could have been formed under forest. They are therefore to be seen as derivatives from former forest soils of which all record has been obliterated by the active pedogenetic processes associated with either the moorland condition or the stages that led up to it.

The evidence so far presented about the original forest soil type is necessarily incomplete, but it seems clear that on the Tabular Hills there was originally an unbleached soil; in the lowland heaths of the New Forest and Dorset, proof is lacking but it may be deduced that the same may have been the case, while in the Cleveland Hills there is only scanty evidence of unbleached soils from the barrow mounds. One indirect source of evidence has so far not been mentioned, namely the buried levels found in a number of these sites and described in detail elsewhere (35). If these levels represent old land surfaces covered over by transported material, their degree of bleaching might give some guide as to the soil condition at the time of burial, even if they were somewhat disturbed in the process. Unfortunately, the picture is often obscured by later soil development, and this applies to all the lowland examples except one, Burley Heath. Here it is quite clear that the layer of soil in which forest pollen is found (horizon VII) is not bleached. The other cases—Chick's Hill Barrow, Coldharbour, Decoy Heath, Oakhanger, and Pondhead—all show the buried level in the A_2 horizon, so that it is impossible to say whether it was originally bleached or not. On the other hand, three examples are known from the Tabular Hills, namely Bickley Moor, Reasty Top Barrow, and Suffield Moor-Heath, and in each case the soil below the level is clearly unbleached. In the two latter cases the thin iron-pan was formed at the interface.

There is, however, one of these examples which suggests that the buried level was the surface of a leached soil—that is Keston Common (Plate II, 4). The buried surface lies in the B horizon of the present humus–iron podzol and below it the material is distinctly less iron-rich, though it becomes richer again further down the profile. This could be explained on the assumption that the transported material was dumped on the surface of an existing podzol and that, in spite of the development of podzolization from the new surface, resulting in the formation of the new B horizon round the old surface, traces of the earlier A_2

still persist. This hypothesis gains some support from an adjacent site, Keston Camp. This is an Iron Age hill-fort with a complex rampart system. A section through the ramparts revealed the buried soil (Plate VII, 2), which was a humus–iron podzol (for analyses see Cornwall, 16). However, in contrast to other lowland sites, pollen analysis showed that this site had never been occupied by heathland but was in fact under oak forest at the time of construction of the ramparts. There was nothing to suggest that this forest was secondary; on the contrary, its rich woodland flora confirmed its primary nature.

Other indications have been found that the deciduous forest climax may have been associated with a podzolized soil in some places. At High Rocks, for instance, though no soil profile was preserved, a Mesolithic site was overwhelmed by sand which was rich in forest pollen and which was intensively bleached. At Portesham (113) a Bronze Age barrow covered a well-developed podzol, although there was no evidence of earlier heathland conditions.

Portesham was interesting because it was a mound built of orange subsoil and yet the surface of the mound had produced quite a well-developed humus–iron podzol since it was built. This is in marked contrast to the soil development at the surface of other earthworks constructed of subsoil. Lyndhurst Ridge, for instance, shows the merest trace of iron movement in the 660 years since its construction. Less easy to interpret, because of the artificial layering of the mound, is Burley Barrow, over 2,500 years old; while it is impossible to be sure just how iron-rich the surface layer was, it is still not bleached and the soil is essentially 'brown'. On the other hand, earthworks which are shown by pollen analysis to be constructed of topsoil show marked degradation at the surface: the thin iron-pan soil on Bickley Barrow, the humus podzols of Chick's Hill and Springwood barrows, the peaty gley of Burton Howes 4D. Even the earthworks at Keston fall into the same pattern; the original ramparts constructed of subsoil show unbleached profiles today, while the later enlargement of the new rampart by the addition of topsoil has developed a humus podzol. If the Keston parent material, which has been shown to have produced a humus–iron podzol before deforestation, can resist podzolization for 2,000 years, this emphasizes the inherent liability to podzolization which the parent material at Portesham (Bagshot Beds gravel) must have.

In conclusion of this section it may be said that though there are sites which appear to have carried podzols even under undisturbed deciduous forest, in the majority of cases the degraded soils covering extensive areas are secondary and were not the soil types in equilibrium with the uncleared forest. It is apparent that the nature of the parent material has largely determined the type of degradation which has developed in any one region.

V. FACTORS INFLUENCING PROFILE DEVELOPMENT

In the previous section the occurrence of soil types today and in ancient times was discussed and in doing so it was impossible to exclude consideration of the parent material as a soil-forming factor. Other factors, however, must also be taken into account, particularly topography, time, climate, and vegetation.

(i) *Topography*

There was considerable variability in altitude of sites, ranging from near sea-level to 1,500 ft. Nevertheless, there was no clear association of any one soil type with altitude, with the possible exception of the peaty gley which was only recorded on the Cleveland watershed. Even this may have been as much a reflection of geology as of altitude, since it was only at the higher altitudes that clays were met. The thin iron-pan soils were found both at high altitudes and on the lower Tabular Hills at about 700 ft. They were not found in the lowland heaths. The humus–iron podzols of the lowlands, however, also extended upwards as, for example, at Portesham (750 ft. O.D.).

No specific study was made of the relationship of soil profile to topography. The clean-cut topography of the Tabular Hills only interfered in one case, Troutsdale, where woodland, the vegetation type to be studied, only occurred on the steep slopes. Even here, however, the soil was a thin iron-pan podzol, similar to the soils of the plateau. It was frequently observed that the depth of the solum became greater on a scarp edge, and on a scarp the thin iron-pan often gave way to an irregular humus–iron-pan.

Elsewhere the choice of site was determined mainly by uniformity of site and of vegetation, and relatively level ground was usually selected. No selection was possible, obviously, in the archaeological sites.

(ii) *Climate and time*

The role of climate in the development of the podzol is difficult to assess, and the published records of podzols of known date are scarce, mostly referring to the Bronze Age, which is also adequately covered by this investigation. Some podzols very probably existed in Mesolithic times; many more are Neolithic or later, and others can only have originated since the Iron Age. For instance, at Lun Rigg, where Iron Age pottery was buried, presumably by earthworms, it is now cemented into the thin iron-pan. Taschenmacher (111) believes that in Westphalia land-use in the Middle Ages led to podzolization of brown earths, and foresters are familiar with the same process under relatively recent crops (36). In other words, the process has been starting in all periods, in various climates, since the Atlantic or even earlier. Its inception, therefore, is not controlled by climate alone; in fact the burst of podzolization which apparently took place here and in western Europe in the Sub-boreal is hardly in keeping with the usual theories that podzolization is essentially a process of cool damp climates, and the deductions as to climate which have sometimes been made solely on the fact of the presence of a podzol are seen to be quite unwarrantable.

Post-glacial climatic change has been established on a reliable time basis through several independent disciplines. For the present purpose, therefore, the climatic setting of a buried surface can be deduced if its approximate age can be established from the archaeological data. No absolute proof has yet been obtained in these investigations that podzolization occurred before the Sub-boreal (Zone VII*b*), but in certain sites this is not excluded.

For example, the Mesolithic site at High Rocks, in which Neolithic pottery was also present in the secondarily stratified sands, gave proof that the topsoil was already bleached at the beginning of the Sub-boreal, and though no contemporary soil profile was available, the degree of bleaching suggested that this was

not a recent feature. Of the buried levels described elsewhere (35) only that at Keston Common showed bleaching (except those which lay in a later-developed A_2) and some at least of these levels appeared to be of Atlantic date.

The occurrence of slightly degraded brown soils and immature podzols under Bronze Age barrows is a strong indication that the podzolization process had not been operating for long, since it is unreasonable to assume that these profiles represented the degree of leaching attributable to the whole of the post-glacial. From Goodland in Northern Ireland comes evidence that a podzol developed between Neolithic forest clearance and the onset of deep peat formation (in Case, 12), the podzol being formed entirely within the Sub-boreal and before the climatic deterioration which marked the onset of the Sub-atlantic (Zone VIII).

Only two buried soils have been examined from the Sub-atlantic period itself (apart from Lun Rigg, mentioned above). One, from beneath the rampart of an Iron Age camp at Keston, was the best-developed prehistoric podzol recorded. The other, a podzol buried in medieval times (Lyndhurst—The Ridge), was apparently then as intensively developed as the present-day heath soil outside the earthwork.

It is to be expected that the soils under the latest earthworks will be the best-developed. This may merely be a function of time and cannot be taken as evidence of climatic influence, even though there had been a change of climate. The data provide no correlation between the onset of podzolization and climatic conditions. It is true that, in general, bleached horizons were not present in the Atlantic period, whereas they occurred throughout the Sub-boreal, but a closer analysis shows marked regional differences. From the soils under barrows in the Tabular Hills it appears that podzolization started considerably later there than in the south. Moreover, within any one region considerable differences may occur in the development of the fossil soils. For example, podzolization of the soil under the Late Bronze Age barrow at Burley was less advanced than in the soil under an earlier Wessex barrow at Portesham. These variations could only have occurred if some other factor (or factors) was at times strong enough to override climate as a soil-forming factor.

That this can be the case is proved by the range of soil types one finds today—even on one parent material. For instance, near Burley, all within a short distance of the barrow just mentioned, may be found a brown forest soil, a degrading brown soil, and a humus–gley podzol. Elsewhere in the New Forest similar and even more striking juxtapositions have been reported from the Plateau Gravels (36); an example may be seen in Matley Wood and the adjacent heath. In north-east Yorkshire, too, isolated patches of unpodzolized soil may be found on the same parent material as heath, but they are scarcer and have not been studied in detail. It seems clear from the above observations that the onset of podzolization is not attributable to any particular climatic phase of the post-glacial, nor is the development of the profile simply a function of time.

(iii) *Vegetation*

Here we must look broadly at the evidence associating vegetation and soil types, without entering into a discussion of the mechanism of vegetative change, which will be dealt with in detail in the next section. Such evidence is

inevitably incomplete; good pedological data are not always accompanied by good palynological records, and vice versa.

Particularly does this apply to the initial forest phase, to which some reference has already been made. The best evidence about the floristic composition of the original forest comes from the high-altitude moors, but there is not a single soil profile which can be associated with that phase. Nevertheless, we should examine the ecological composition of this forest for its own sake, because there appear to be some differences in composition between these high-altitude forests and those of the lowlands. Table I gives the tree-pollen spectra from several Cleveland sites and one Lancashire site, in some cases showing different stages. The Ralph Cross analyses are to some extent exceptional, showing higher percentages of *Tilia*, *Betula*, and *Ulmus* and rather less *Quercus* and *Alnus* than the others. In general, however, the forest seems to have been dominated by *Quercus* (making allowance for its under-representation by pollen) in association with *Alnus* and with *Betula* and *Corylus* as important components. Apart from Ralph Cross, none of the high-altitude sites gives any indication of *Ulmus* percentages approaching those typical of the Atlantic (Zone VII*a*) period. While this may suggest a Sub-boreal or later date for these sites, one would not expect this to apply to the Mesolithic level at White Gill. Indeed, though the pollen record for this site goes back to Pre-boreal times, there is no indication that *Ulmus* was ever significant. It is possible, therefore, that *Ulmus* was never an important component of the upland forest on base-poor parent materials, though it may have occurred on soils now decalcified and have persisted in the more calcareous ravines (Barry, 4). Pearsall (81) has described base-demanding species occurring today along stream courses where the rock is exposed, even though the environs are entirely moorland. In addition to Barry's record of *Ulmus* in such places in the Cleveland Hills, remains of *Corylus* have been found in peat of Sub-boreal age in the same neighbourhood (121).

Not one of the group of sites on the Tabular Hills gives a good record of the initial forest. Usually, the pollen record starts in scrub conditions (*Corylus*, *Alnus*) though small amounts of high-forest tree pollen persist to indicate that there may have been an earlier phase. The likely explanation is that acidification of these sedimentary rocks did not become strong enough for the preservation of pollen until after the forest had been destroyed. Such evidence as there is suggests that the original forest here was intermediate between the upland and lowland types. *Quercus* was often relatively insignificant, sometimes equalled or exceeded by *Tilia* (e.g. Reasty Top buried level), but the way in which *Alnus* could vie with *Corylus* in the scrub stage suggested that it was an ecologically important species (Suffield Moor—Birch, Suffield Moor—Heath, Bickley Moor, Lun Rigg). In the lowland sites, *Alnus* never achieved such importance, its greatest representation being in the buried forest phase in Burley Heath. This analysis illustrates well the characteristic importance of *Tilia* in such lowland situations, as seen also at Chick's Hill (buried level, 35), Lyndhurst—White Moor, and Oakhanger. It is noteworthy that unusually high *Tilia* percentages—by comparison with the values obtained from peats—have been recorded by a number of workers in the lowlands of the Continent. Benrath and Jonas (6) found high *Tilia* values in a buried podzol near Rostock, and in another profile in the neighbourhood the whole of the tree pollen at one level

TABLE I. *Pollen Analyses of Humus Layers (per cent. tree pollen)*

Site	*Stratum*	ΣTP	*Alnus*	*Betula*	*Fraxinus*	*Pinus*	*Quercus*	*Tilia*	*Ulmus*	*Corylus*	NTP
White Gill	5–0″ Above microliths	515	44·3	14·8	1·4	1·2	33·8	1·7	2·7	61·9	103·9
	0–1″ Below microliths	189	51·9	10·1	. .	0·5	33·9	0·5	2·6	35·4	38·6
Burton Howes	4D Turves	331	56·5	9·0	3·0	2·1	26·2	0·9	1·8	86·7	119·3
	1A Turves	132	56·8	9·1	4·5	0·8	26·5	0·8	1·5	100·8	168·2
Winter Hill (Lancs.)	Turves	811	45·7	11·3	1·4	0·5	38·6	1·5	1·0	57·2	101·1
	Barrow floor	268	37·7	14·9	2·2	0·7	41·8	1·1	1·5	38·1	137·7
Ralph Cross	Raw humus 1–5″	259	32·0	28·2	2·7	4·6	26·3	0·8	5·4	71·4	390·7
	Raw humus 5–7″	201	31·8	28·4	4·5	1·0	28·4	. .	5·0	53·2	139·8
	Below raw humus (7–8″)	95	38·9	8·4	. .	2·1	26·3	5·3	18·9	86·3	166·3

was *Tilia*. Scamoni (96) also recorded high *Tilia* values—in one case 47 per cent. of the tree pollen—in sand profiles in Eberswald, and von Bülow (8) recorded analyses in which the whole of the mixed oak forest fraction consisted of *Tilia*. Selle (99), too, found *Tilia* forming much higher percentages of the tree pollen than is usual in peats, but he deduced from this that there was something misleading in the analyses from mineral soils. While it may be true that differential preservation may favour *Tilia*, as postulated by Godwin to account for high percentages found in peats in Yorkshire (14), there seems to be a considerable volume of evidence from various sources that on sandy soils the original forest may have contained a much greater proportion of *Tilia* than is indicated by the general pollen spectra for the country as a whole (see Godwin, 53). It must be remembered that not all mineral soils show high *Tilia* values, so the question is not simply one of differential preservation, and evidence (Østergaard, 79) that *Tilia* still persists in forests on sandy soils in Denmark suggests that the species once had an ecological niche in such situations.

While there is reason to believe that in the Tabular Hills and in the lowland heaths the forest soil was not bleached, evidence has also been brought forward to show that in a few cases a podzol was associated with untouched deciduous forest. The clearest example of this is at Keston Camp and a glance at the composition of this forest is instructive. It is probably a Sub-atlantic flora and therefore not strictly comparable with those mentioned above, but the earlier buried level at Keston Common shows a very similar composition apart from the somewhat higher values for *Tilia*. *Quercus* was the absolute dominant, but was accompanied by a surprisingly large amount of *Ilex*. *Corylus* and *Betula* were the only other noteworthy woody species. The remarkable thing about this list is that *Ilex*, *Corylus*, and *Betula* are all species which have been described as soil improvers (36), yet here they are associated with a well-developed podzol. Their influence in this direction may have been counteracted by the nature of the *Quercus* litter and probably even more by the properties of the soil parent material. It is clear that one cannot postulate the existence of a brown forest soil merely on the evidence that such species were present, without taking into account the nature of the parent material.

A study of the literature shows a conflict of views on the association between deciduous forest and soil type. Neugebauer (77) has quoted examples of contradictions with reference to both *Quercus* and *Fagus*, but he was unable to reconcile them beyond suggesting that the key might lie in climate and parent material. Lossaint (67) has referred to intense podzolization under ancient *Quercus* forest on sandy soils near Strasbourg, and it is not uncommon to find reference to oak as a podzol-forming species (e.g. Pierce, 83). References in the literature to the association of deciduous forest and brown forest soils are too numerous to list, but from what has been said it is apparent that the question is not straightforward. Once it has been established that historical disturbance may be ruled out (33), further investigation is necessary, particularly into the properties of the parent material and over a wide geographical range.

There is abundant evidence from the sites described here to give a picture of the degeneration of the forest, and this can be associated with the soil sequences already described. In the majority of buried soils the palynological evidence suggests that the earthwork was built in a clearing or in open country, so the

soil profile can only be related to that condition and not to any near-by woodland phase. The proximity of woodland, however, may sometimes be gauged roughly from the pollen spectrum. It seems reasonable to assume that, since the woodland was progressively being driven back (32), the larger the clearing the older it was.

The analyses of the prehistoric surfaces have given evidence of the state of the vegetation at that time. These are summarized in Table II. It has been necessary to make these calculations on three distinct bases.

1. The NTP/TP percentage is the standard measure of the openness of the countryside (Jonassen, 61).

2. The herbaceous and suffruticose plants will only produce pollen freely in the open, so this group has been taken separately, and the individual percentages based on the NTP total (which excludes spores). In every case in Table II it appears that there are plants of this group on the site, so that this representation illustrates broadly their relative importance.

3. *Corylus* and *Pteridium* are expressed as percentages of the total pollen and fern spores. Spore production in *Pteridium* is not confined to the open, and both types would exclude the field layer by direct competition. It is considered likely, therefore, that where they occur in quantity they are marginal to the places sampled; otherwise they would have eliminated the lesser plants.

It should be made clear that the samples compared in Table II vary somewhat in their nature, but are chosen as the best possible source of contemporary pollen. In the first group of three barrows the buried soil was truncated, so that there was no contemporary surface *in situ*. The turves used to construct the mounds were therefore used for these data. In other cases there was no obvious humus layer at the surface, the sample being primarily mineral. This may lead to some error due to earlier pollen, but an inspection of the whole profiles in each case suggests that this will not alter the general pattern of the spectra.

The barrows from the high moors show the closest relationship with forest. The turves of Winter Hill and Burton Howes barrows came from open woodland, with *Corylus* well represented. Where light was adequate *Calluna* and grasses were predominant, the latter to a much greater degree than is normal in present-day Callunetum. The turves from Burton Howes Barrow 1A showed a somewhat later stage, with a greater influence of non-tree vegetation. In none of the examples was there any evidence of cultivation. Since the buried soils had no turf-line and the turves of the mounds had no complete soil profile attached, the association of soil and vegetation cannot be reliably determined. All that can be said is that mineral material attached to the turves varied inconsistently in the degree of bleaching; in other words, the upper layers of the soil may have been in an actively transitional state. There was no evidence that the more bleached turves differed significantly in pollen spectrum.

The two barrows at Springwood and Reasty Top, close together geographically, showed developmental trends in vegetation and in soil. On both sites the immediate surroundings were deforested, though *Corylus* scrub was abundant in the vicinity; both showed a higher representation of *Pteridium*, and the high *Plantago* value for each strongly suggests cultivation. The Reasty Top Barrow, however, showed a greater influence of Ericaceae, and this could be correlated with its more developed profile. It should be noted, however, that the two profiles under Springwood Barrow showed that though leaching was taking

TABLE II

Site No.	Name	NTP/TP per cent.	Percentage of ΣP		Percentage of NTP			Σ NTP
			Corylus	*Pteridium*	*Calluna*	*Gramineae*	*Plantago*	
XXXIV	Winter Hill Barrow (turves)	101	21	1	37	41	1	820
VIII	Burton Howes Barrow 4D (turves)	119	27	2	62	28	2	395
VII	Burton Howes Barrow 1A (turves)	168	26	3	53	37	1	222
XXVIII	Springwood Barrow (sum of 2 spectra)	289	31	11	32	16	26	81
XXVII	Reasty Top Barrow	266	30	14	59	26	8	413
IX	Chick's Hill Barrow	287	13	19	57	19	4	341
III	Burley Barrow	260	14	32	66	14	4	125
II	Bickley Moor Barrow (sum of 2 spectra)	1,088	20	4	..	54	37	283
XIV	Goodland (sum of 2 spectra)	1,722	7	1	4	76	10	775
..	Heath today (average of 10 sites)	850	5	2	83	10	2	..

place, it was more pronounced in the profile with the smaller percentage of Ericaceae pollen.

Chick's Hill Barrow (2) and Burley Barrow showed a very similar condition to the two just described. The influence of *Corylus* was less and that of *Pteridium* greater but the sites were apparently under grass-heath. The soils were both immature podzols, though considerably more developed than those under the two Yorkshire barrows.

The remaining two sites were in quite open country, though *Corylus* scrub was better represented in the neighbourhood at Bickley Moor than it is in heathland areas today. In fact the site of the Bickley Moor Barrow was not heath but agricultural land at the time the barrow was built. Moreover, the soil was not podzolized at that time. Goodland, on the other hand, though very similar in the vegetation at the time it became peat-covered, had a shallow thin iron-pan soil, and the pollen analyses show that this had developed entirely during the grass phase (12).

From the data presented here it is apparent that no good correlation with vegetation can be traced. The degradation of woodland through cultural influences resulted in the spread of some form of grass-heath, and this was usually accompanied by increasing soil degradation. That this was not due to the increasing effect of *Calluna* is shown both by the Springwood analyses and also by Goodland, where the soil development took place in the absence of *Calluna*. Similar conclusions were reached by Waterbolk (116) for the Dutch heaths. More recently he has shown (117) that occasionally heath podzols did occur under Neolithic barrows in Holland and that in such cases *Calluna* pollen was present in large proportion in the buried surface. Nevertheless, this is not in itself proof that *Calluna* created the podzol; merely that it represented the end-point of the sequence, albeit at an earlier date than usual.

It has already been deduced that the onset of podzolization is not to be correlated with any particular climatic phase; certainly the process was active long before the climatic deterioration of 500 B.C. Now that it appears that the presence of *Calluna* is not an essential requirement of this process, this disposes of the argument sometimes put forward that our heaths and their soils are the result of the spread of *Calluna* in response to the climatic deterioration. It is more than likely that this deterioration would weld the acid-tolerant *Calluna* and the acid-developing podzol into a more closely-bound unit, but it would be wrong to assert that it was the cause of the formation of British heathlands.

Even today quite strongly developed podzols may be found under grassland, as for instance the grass-heaths of the Breckland (Watt, 118). One cannot be sure without specific investigation that in the history of these soils grass had always been the ecological dominant; though Watt presents a sequence of soil types—all under grass—it is difficult to believe that these represent a developmental sequence, a conclusion which Watt himself refused to draw. Certain types of Callunetum may have a good deal of grass in them which may become temporarily dominant after fire (e.g. *Molinia* in some New Forest heaths), but since this dominance is short-lived, *Calluna* will have an overriding effect in the long run.

The relationship between other vegetation types and the development of the podzol is difficult to assess from these data. The prehistoric soils probably came

from clearings in the woodland since the pollen of both light-demanding herbs and shrubs is represented; under the shrubs themselves the proportion of other pollen should be less. Consequently, one cannot say whether podzolization was active under *Corylus* and *Alnus* or whether it was confined to the cleared areas. Crocker and Major (17) reported more rapid acidification of newly exposed glacial soils under *Alnus tenuifolia* than under other vegetation types, but this could hardly be termed podzolization at such an early stage (35–50 years). There is no evidence from contemporary British ecology that either *Corylus* or *Alnus* brings about soil degradation; on the contrary, both would generally be regarded as soil improvers, although the conflicting evidence from Keston has already been referred to.

VI. THE TRANSITION FROM FOREST TO HEATH

It has been mentioned above that the most consistent evidence of forest conditions comes from the high-altitude sites of the north, though good evidence also comes from scattered sites in the south. However, it is from the northern sites that the best evidence of progressive deforestation may be obtained. In the White Gill profile, the pollen sequence probably starts in the Pre-boreal, culminating at the top of the mineral soil in a pollen spectrum indisputably representing forest (NTP/TP = 39 per cent.). This level was associated with Mesolithic microliths and above it raw humus had formed, in which the pollen spectrum indicated more open forest conditions (NTP/TP = 104 per cent.), with grasses and *Calluna* showing some increase.

Into this pattern may be fitted pollen spectra from the Burton Howes, at an altitude of over 1,400 ft. on the Cleveland Hills, only 70 ft. below the highest point of these hills. Two of the barrows were examined, and though the soil beneath each was truncated the turves of which they were built served to give contemporary pollen spectra. Both gave good evidence of forest conditions in the neighbourhood. The larger one (4D) gave a NTP/TP percentage of 119 for the turves of its core; soil which had been used to build it up after a later cremation had been inserted gave a percentage of 150, indicating the recession of the forest in the interval. The other mound (1A), which had not been extended, gave a percentage of 168 for its turves, showing that the forest was still further away. Either the barrow was that much later or it was placed further from the edge of the clearing. The closeness of the two barrows, however, renders this last hypothesis unlikely; it is more likely that the barrow 1A was in fact later.

For comparison it is interesting that the Bronze Age barrow examined on Winter Hill in Lancashire gave parallel results. Here there was a buried humus layer under the barrow which gave NTP/TP = 138 per cent., in contrast to the turves of the mound which gave 101 per cent., probably indicating that the barrow was built in a clearing in a wooded area.

The last of the high-level sites, Ralph Cross, shows the transition to moorland. Raw humus started to accumulate at the Sub-boreal/Sub-atlantic transition.

At first the NTP/TP percentage (5–7-in. depth) was 140, comparable with the Bronze Age figures given above, but in the top 5 in. of the profile it averaged 391, clearly showing the spread of open conditions.

The evidence from sites at lower altitude, in contrast, is seldom direct, largely because in most of the analyses the pollen record starts after deforestation has set in. At Pondhead a forest phase was seen to precede heathland, but it is likely that this was not primary forest, because of the high proportion of *Betula* and *Pteridium*. A more undisturbed forest seems to have been in existence before the 17-in. surface was buried. In fact, the buried levels sometimes give the best indication of the early forest phase (e.g. Burley Heath). Evidence of a supporting nature comes from other sources: old root channels are sometimes clearly outlined by the hardpan (Plate I, 1) and in one instance *Quercus* charcoal was recovered from such channels, apparently resulting from the burning of the roots *in situ* (124). Such root channels, incidentally, indicate that at the time when they were formed there was no restriction of the rooting depth as there is now. In Dutch heath soils Jongerius (62) has found faecal pellets of a soil fauna characteristic of a forest biome, a fauna which is not present today.

It must now be considered why the original forest disappeared so completely. Deciduous forest today covers a wide range of climate and soil, and while changes in these factors might be expected to alter the floristic composition of the forest, it would need changes on a big scale to bring about its elimination by these factors alone. The dominance of the forest over its environment would hardly be destroyed unless the dominant life-form itself was destroyed. There is ample evidence to show that whatever climatic and soil changes have taken place during the last few millennums, they have not been sufficiently drastic to eliminate the deciduous tree as the natural ecological dominant in these islands, at any rate at the altitudes we are dealing with here.

Yet change on such a scale did take place and apparently went hand in hand with soil deterioration. Pearsall (82) has correlated soil deterioration and forest clearance in the Lake District, but he suggests that the soil changes were already showing up before any possible human interference; that is, before Neolithic times. This involves an assumption which must be examined more closely, namely, that before Neolithic man came on the scene the environment was unaffected by man. A study of the existing literature on this point reveals some widely divergent views. The traditional view is simply expressed by Mitchell (71): 'Mesolithic man, ignorant of agriculture and of animal husbandry, was content to be confined by the forest to the margin of sea, lake and river.' Childe's conception (1931) is quoted by Darby (20) as recently as 1956: 'Mesolithic hunters and food-gatherers, opening up small areas for their dwellings, using tree-trunks for boats, and finding in the forest both fruit and game', while Iversen (58) maintained that in Mesolithic times 'the development of the woodland was determined solely by climatic and other natural forces'. These pictures do not accord with the fact that Mesolithic remains have for long been known from our moorlands, occurring beneath the peat and often associated with charcoal. The Mesolithic site at Oakhanger, though a lowland site, showed clearly the use of fire by Mesolithic man. This use of fire by man from the earliest times has been forcibly set forth by Narr (75) and by Stewart (104), who specifically dispute the view that Mesolithic man did not influence his environment. Sauer (95) goes

even further, suggesting that in some areas, such as the arid prairie lands, man has prevented the development of anything but a fire-climax vegetation, since he has been operative throughout the post-glacial period. West (120) has suggested that even Palaeolithic man may have caused deforestation by the use of fire.

If it can be established that Mesolithic man did use fire to drive his game and to open up the landscape for hunting (to say nothing of periodically losing control of it), then the ecologist must accept that the environment would be altered drastically. Even during the Atlantic period, though there was primarily a damp climate, the edaphic conditions of sandy and chalky country, especially uplands, would have carried a drier type of forest, one more susceptible to fire, and one less able to regenerate itself freely, than that of the rest of the countryside.

It may be more than coincidence that the spread of bogs, heath, and other open communities at the expense of woodland took place on the Pennines at a time contemporary with microlithic industries; even traces of early agriculture have been recorded within Zone VII*a*—the Atlantic period (Walker, 115). Referring to other Pennine sites, Woodhead said as long ago as 1929 (123) that opinion was growing that 'here, as elsewhere in Europe, the history of man is ultimately associated with the history, development and ultimately the destruction of the deciduous forest'.

Perhaps it is significant that peat formation was sometimes very slow at first (Conway, 15), though generally dating back to the Boreal/Atlantic transition. Our knowledge of the Mesolithic population at this time is, of course, very sketchy, since it left no permanent structures as did later cultures. Even assuming that it was as small as is sometimes thought (e.g. Fleure, 50) it must be recognized that the use of fire by these people would have an effect out of all proportion to their numbers, a point discussed at length by Stewart. Alway and McMiller (1) have shown that burning in a deciduous forest area may not only cause the establishment of a poorer forest type, but that it brings in its train greater acidity, a decrease in bases, and a lower nitrogen status. It also happens that the secondary vegetation is often itself more liable to burn, so that a vicious circle is set up. That fire would have modified the forest type and brought loss of soil structure and nutrient resources seems inescapable, bearing in mind the centuries over which the process would have operated. Such an upset of the ecological equilibrium, it seems to me, would be a *sine qua non* for the replacement of the forest by peat on the higher lands, and its replacement by other vegetation types in the lowlands. Steensberg (102, 103) maintains that a slash-and-burn fire developing too high a temperature at soil level will lead to soil exhaustion and the spread of heathland.

Both the Mesolithic sites included in this investigation gave strong support to the view that this culture affected its environment quite markedly, at any rate locally. It was mentioned above that the pollen spectra from the organic matter overlying the flint layer at White Gill showed a higher NTP percentage than the surface below (Table I). There was an increase in grasses and other herbs, and an increase of *Betula* at the expense of *Alnus*. The presence of charcoal of *Quercus*, *Alnus*, *Betula*, and *Corylus* with the artifacts shows that the forest was being burnt. The other example, Oakhanger (86), gave evidence of a change from woodland to heath, accompanied by progressive soil acidification. Neither of these sites appears to have been occupied by later cultures. Beijerinck (5), however, records

Mesolithic artifacts in the bleached sand of Dutch heath soils, with Neolithic remains lying above them in the profile.

Before leaving this discussion of forest deterioration, a few words will not be out of place on the subject of man's use of individual forest species. Today we have lost most of the forest lore that primitive people would have possessed and on which their existence probably depended. It is likely that plants were used by early man for food and textiles, and such usage might have affected the ecological status of these species in a manner that we do not realize today. Mitchell (72) has suggested that the disappearance of *Ulmus* from the Irish forests was not a climatically-determined change but was associated with human populations; he thus questions the use of *Ulmus* as an indicator of climatic change in pollen analysis. This view is supported by the work of Nordhagen (78), who has investigated the use of certain trees for food and other purposes even in historic times. In times of famine in Scandinavia bark-bread was prepared until as recently as last century, and in southern Sweden the most important source of meal was *Ulmus glabra*. Other species were also used, notably *Pinus silvestris*, *Populus tremula*, and *Betula* spp. Moreover, *Ulmus* and *Sorbus aucuparia* have been and are still used as fodder for stock. Nordhagen refers to the geographical restriction of *Ulmus* due to such usage, and he describes how the method of bark-stripping must greatly reduce pollen output even though the trees are still present.

In a similar way, the distribution of species might be affected by their use for bast. To some extent *Ulmus* was used in this way too, but the favourite tree for this purpose was *Tilia*. Since *Tilia* is another species upon which pollen analysts base climatic deductions, this factor may be of importance.

It is very probable that other trees were also extensively used by prehistoric man, and in particular *Corylus* seems to offer such possibilities, but species that were abundant are unlikely to have been influenced to the same extent as those which only occurred in small proportions (Nordhagen). Nevertheless, features of *Corylus* distribution, which have been seen as of climatic origin for so long, may prove to be governed partly by other factors. Rawitscher (87) suggests that the *Corylus* maximum in the Mesolithic may be related to the use of fire by Mesolithic man, and he draws the contrast between Europe and North America in this respect.

So far we have been discussing man's influence through the pre-farming cultures, but attention must now be directed to the effects of more specific activities associated with herding, pastoralism, and eventually with agriculture. A glance at the map will show that the British heathlands are liberally sprinkled with prehistoric remains in the form of tumuli, entrenchments, pits, &c., which belong to a wide range of cultures. Other evidence of human occupation frequently exists and is not recorded on the maps since it leaves no important surface configurations. Apart from Mesolithic remains, relics of the Iron and Bronze Ages and the Roman period may come within this category.

It is obvious that the heathlands as we see them today would not support a human population, and some of the earlier writers (e.g. Elgee, 45), who believed that heathland was a natural environment, were unconvincing in their attempts to fit the prehistoric peoples into it. We now realize the very considerable deterioration that has taken place.

On some soils the mere fact that the tree cover was removed, whether or not combined with the effects of fire, might have caused deterioration. It is pertinently observed by Darling (21) that woods on acid soils have a more calcicolous flora than grazing grounds outside, probably due to the ability of deeper roots to bring up minerals from lower horizons (frontispiece) and so counteract the tendency towards leaching (26).

Exactly the same explanation was put forward by Leaf (66) to explain the loss of fertility in woodlands which were subject to grazing. Romell (91), too, in discussing the fertility of the Swedish *Enge(äng')*, points out that fertility of these 'leafy meadows' dropped after a number of years' cropping, but that by leaving them untouched for some years the fertility built up in the resulting thicket until a satisfactory yield could once more be obtained. He suggests (92) that the initial fertility after felling, the so-called assart effect, is due to the release of available nitrogen through the decomposition of the roots of the felled trees. However, factors other than root relationships are also important, since grazing or mowing imply the removal of part of the nutrient capital from the area. Duchaufour (43) has shown that even the simple process of cutting ground vegetation for litter—a long-standing practice—depletes the base reserve of poor soils, though he has no evidence that it leads to podzolization.

It should be borne in mind that, as a result of deforestation in the Mesolithic period, grazing by wild animals, e.g. deer, would be intensified. Just as the North American Indian is said to have increased the buffalo herds by providing larger grazing grounds (Roe, 90) so Mesolithic man may have increased his game supply (and its accessibility). In doing so he would also have added one more weapon to his equipment in the fight against the forest, namely grazing itself. As an incidental factor in a balanced biome it would be insignificant, but once concentrated, the retreat of the forest would be signalled.

Pearsall (80) maintains that grazing has been the greatest single factor in woodland destruction in northern Britain, and Ellenberg (46) believes that heaths in north-west Europe arose from forest pasture dating back to Neolithic times in a forest type which had a low resistance to such activity. Combining this with Darling's assertion of increased leaching in grazed land, we come back to the earlier reference to Pearsall's observations that soil deterioration started, albeit slightly, before Neolithic times. In view of what has been said it cannot be assumed that this was purely the result of climate and normal maturing processes. It has been said that soil deterioration goes on under oak forest, but that man's influence is to speed the process up (Duchaufour, 39); before accepting this as generally true, however, we must know more about the extent to which man's influence on the forest could be regarded as negligible.

On the areas which are now heathland the main impact on the forest would have come in Neolithic or Bronze Age times. This forest may not always have been a primary forest; it could frequently have been regrowth after earlier deforestation. There is very little evidence of Neolithic occupation of the acid soils in Britain, at any rate in the east and south, the region in which typical heaths occur. This is not to say that the Neolithic period left no mark on the vegetation of acid soils. The finding of Neolithic arrowheads from time to time suggests that hunting took place, and it is probable that this would result in the disturbance of the ecological equilibrium even if it had not already been

disturbed in Mesolithic times. When the first Bronze Age people settled on the more acid land, therefore, they may not have been encountering virgin vegetation. It has been shown that in the south of England the earliest barrows, though occurring in more wooded country than the later ones, were nevertheless not built in high forest. *Corylus* was the dominant species, and even at this date the Ericaceae formed a considerable fraction of the non-tree pollen (32, 84). In Yorkshire this was less marked.

Iversen (58) has collected most valuable data on vegetation changes when the first agricultural people settled in Denmark, the particular value of these studies being their sequence. The crude analyses described in this paper cannot be used to construct a similar picture for the English heathlands, but they do provide data which can be linked with Iversen's pattern of change. The two main cultures in Jutland were the Megalithic (Funnel-beaker) on the more fertile eastern side, and the somewhat later Single Grave culture on the poor soils of the centre and west. The Megalithic impact on the forest was characterized by the régime of *Brandwirtschaft*, the use of fire to clear the forest and to provide the seedbed for crops in one operation (cf. Steensberg, 102, 103). Clear-cut evidence of the three phases, (*a*) clearance, (*b*) period of culture, and (*c*) regrowth after abandonment, was obtained from the pollen analyses of bogs in the vicinity. The use of fire was indicated by charcoal layers in the peat, coinciding with the increase of non-tree pollen and a decrease in tree pollen. Then followed a phase in which *Betula* was predominant, but this gave way to *Corylus*. The non-tree pollen types were primarily grasses and *Plantago*. This pattern contrasted with that produced by the Single Grave culture. Here there was no evidence of fire, and, significantly, *Betula* did not become prominent. The culture plants were also relatively poorly represented.

It is recognized that these cultures were Neolithic, a period not properly represented in our sites, but the vegetation history as provided by the soils beneath Bronze Age barrows might reasonably be expected to cast some light on the earlier period. It is perhaps significant that as a rule *Betula* is poorly represented in the lowland sites, and in so far as such negative evidence goes, it implies that *Brandwirtschaft* had not been intensively practised. Iversen suggests that the Single Grave people did not clear with fire because the forest on the poor soils was open enough to render such clearance unnecessary, and in any case these people were nomadic herdsmen and not cultivators.

In Britain, as far as these investigations allow a statement to be made, there seems to be a clear division between Bronze Age activities in the highlands and lowlands. The three barrows at high altitude (Burton Howes 1A and 4D, Winter Hill) all told essentially the same story. The forest was being opened up, but there was no evidence of agriculture. Where comparison is possible, there was an increase in the proportion of *Betula* (cf. Winter Hill and Ralph Cross, Table I) and a decrease in *Alnus*, reminiscent of the change at White Gill due to Mesolithic burning. It may be concluded, therefore, that fire was being used, and that the culture was pastoral rather than agricultural, a conclusion in close agreement with Pearsall's view. The gradual rather than sudden disappearance of forest and *Corylus* thicket from these hills—extending well into the Sub-atlantic—tallies with the influence of ranging grazing animals. The forest was not completely replaced by *Corylus* as it frequently was in the lowlands. The persistence

of *Quercus*, with percentages varying surprisingly little, is also in contrast to the lowland condition.

The cultivation of crops apparently took place only at lower altitudes (but including the Tabular Hills). It may have been a form of shifting cultivation, for the regeneration of scrub following agriculture was suggested in at least one site (Reasty Top Barrow). Nevertheless, *Corylus* scrub, sometimes accompanied by *Alnus*, was a constant feature of these analyses. We remember that on the Jutland heaths *Corylus* was regarded as the progenitor of the returning forest, and it may have been so on the English heaths, but we must also remember that there seems to have been a continuous occurrence of *Corylus*, without break, from the Boreal period onward. In fact, dominance of *Corylus* may represent forest either going out or coming in. By itself, therefore, it is an indicator of change but not of the direction of change.

Since much of our information on this period has come from the pollen analyses of barrow floors, and these analyses are by their very nature applicable only to each particular site, it is not to be expected that a clear general picture will emerge. Moreover, one is faced with the possibility that there was a deliberate policy in the siting of barrows. They are frequently built of topsoil and the analyses suggest that the land on which they were built was agricultural land, possibly abandoned (e.g. Springwood Barrow), since they sometimes have a very rich weed-pollen content. However, a pollen spectrum does not distinguish clearly between arable and pasture: the Compositae, Ranunculaceae, and *Plantago* may be found in fair quantity in either. Neither is the content of grass pollen a good guide; intensive grazing does not allow pasture grasses to flower freely, so that the pollen spectrum could be low in grass pollen, and so might resemble, say, a weedy arable field. The *Plantago* pollen, wherever recorded, has been predominantly *P. lanceolata*. The only reasonably certain evidence of arable farming is cereal pollen, and this occurs in such small quantities that it is difficult to be sure whether it applies to the site itself or to the near vicinity. However, the consistent occurrence of cereal grains in successive samples, combined with a variety of weed pollens,.is highly suggestive of cultivation, and moreover, contrasts strongly with the upland spectra. Perhaps most significant is the rare occurrence of a cluster of cereal pollen grains, apparently derived from a fallen anther; they are unlikely to have been carried far in this condition.

It seems clear that cereals have been grown since the Middle Bronze Age (if not earlier) in north-east Yorkshire (e.g. Springwood Barrow), though the buried soils of some barrows (Reasty Top Barrow, Bickley Moor Barrow), gave no cereal pollen. Cereal-growing is likely, therefore, to have been patchwise rather than extensive. The discovery of several saddle querns on the heaths of the Tabular Hills suggests that arable agriculture was practised there.

The fact that cereals could be grown, combined with the presence of basiphilous species such as *Corylus* and *Alnus*, demonstrates the superior fertility of these areas in Bronze Age times relative to today. This conclusion is confirmed in an unexpected manner. Archaeological work in north-east Yorkshire has revealed a number of hearth sites lying at a depth of about 3 in. below the present surface of the mineral soil (Lamplough, unpublished). These contain not only charcoal but also fragments of Bronze Age pottery and, more significantly, reddened stones of the local grit. These hearths lie in the upper part of the

bleached A_2 horizon of the heath podzol. The fact that the stones are reddened proves that at that time the soil was not bleached as it is now; they predate the podzol, thus agreeing with the view that the formation of a bleached A_2 is post-cultural. More than this, however, these sites point to active burial agencies, presumably earthworms, having been at work. All these features add up to the existence at that time of a brown soil and not a podzol.

Similar conclusions may sometimes be drawn from other sites. In the Goodland soil, pottery of Neolithic age had been buried apparently by earthworm activity, and subsequently cemented into an iron-pan deposit, the latter presumably only having formed after earthworm activity had stopped through increasing acidity. In an Iron Age site on the north-east Yorkshire Moors (Lun Rigg) pottery was similarly buried at pan depth, and the pollen analyses showed abundant evidence of *Alnus/Corylus* scrub and agriculture.

Iron Age sites on heathland areas are relatively rare. They may be missed through absence of surface traces, but they may also be scarce because the site fertility had dropped to such an extent that it did not allow the development of the more arable type of farming practised in this period. We may recall the observation of Jensen (see p. 12) that cultivation at this time in Denmark appeared to be associated with the forest margin. This could be a result of soil deterioration in the open, the only chance of success being to tap the fertility remaining in the forest land itself (cf. also the Swedish *Enge*, pp. 29, 42). Records of later cultivation are very scarce and usually associated with intensified land-use in war-time, made possible only by heavy fertilizing.

Once man had influenced his environment to this extent, the point had been reached where the environment influenced man. Many heathland areas are very exposed places, so much so that some ecologists have maintained that exposure alone could maintain them as heath. This is a moot point, but the protection that is offered even by a young plantation on such areas is very marked. The ultimate replacement of the scrub vegetation by a suffruticose or herbaceous community must in itself have rendered large areas virtually uninhabitable, particularly in upland and coastal regions.

Since Iron Age times heathland areas have generally been regarded as wastes. The Romans penetrated them to establish lines of communications; Scandinavian settlers used them for summer grazing. Certainly in north-east Yorkshire sheep-rearing was carried on by the monasteries on a large scale from Norman times onwards, and this practice continues even now, though on a reduced scale since the Australian wool market was opened up. However, the use of the moors as grouse moors has continued the treeless state, since periodic burning is as necessary for the health of grouse as for the production of browse for sheep. Burning is also carried out as a preliminary to turf-cutting, which has been carried on throughout the ages and is still practised. Such assaults have not been so intensively maintained on heaths in the south, which are as a rule more tree-covered. The southern heaths are generally smaller in extent and therefore more easily colonized by trees; even the more austere northern ones, however, will become tree-covered where seed is available.

It is an unfortunate feature of the soil-pollen analyses that they are relatively unhelpful as a source of information about the transition from the *Corylus*/grass-heath mosaic phase to the present pure heath. In the mineral soil the former

phase is usually predominant, but as soon as one passes to the raw humus the record changes abruptly to *Calluna* dominance. Reasons why this should be so are obvious. As acidification of the soil increased and earthworms disappeared, there would soon develop a tendency to form raw humus, particularly under certain types of vegetation, notably *Calluna* and *Pteridium*. Raw humus is susceptible to destruction by fire, not to mention turf-cutting, and the pollen record of the intermediate phases will have been destroyed with it. Consequently, a sharp 'unconformity' between the pollen spectra of the mineral soil and the present raw humus (of much later date) will appear. Under forest conditions this sharp break is not always found; some of Scamoni's diagrams show a gradual transition from the mineral to the humus layers, though many do show a sharp break. It may be that this depends on whether or not the forest floor has been burnt since raw humus started forming.

In brown soils with mull humus a more continuous record is found, though it does not usually extend over such a long period of time; for example, this appears to be the case in Burley Oak. In this analysis there is no consistent occurrence of the more ancient types such as *Tilia*, while the presence of *Ilex* at all levels also betokens recency, since analyses from the near-by barrow show *Ilex* to have become abundant only since the Late Bronze Age (see also Matley Wood). These analyses show that the present woodland phase—at least 200 years old, judging by the size of the standing timber—was preceded by more open grass-heath conditions with *Pteridium* playing a predominant role. There was a suggestion of an earlier *Corylus* phase at the base of this profile.

This is reminiscent of Matley Wood, in which *Corylus* also increased at lower levels. This site, however, had clearly been cultivated, since cereal pollen was present, but it was abandoned, passed through a succession to woodland, was temporarily reclaimed, and finally passed over to oak forest, which occupies the site today. Since the largest trees are 250 years old, the pollen record must cover many centuries.

It is possible, therefore, that the increase in *Corylus* seen in the lowest levels of such profiles can be correlated with the *Corylus* phases so clearly recorded in the heath soils, though it must be accepted that on the unpodzolized sites the *Corylus* stage may have persisted longer than on the podzols.

In general the deterioration in soil fertility seems to have become serious towards the end of the Bronze Age, and some stock must be taken of the possible reasons for it. It is tempting to link this with the climatic deterioration about 500 B.C., as Jonassen (61) had done in Denmark, but it is difficult to establish absolute chronology. Moreover, we know that site deterioration started long before then, though it was not until the Late Bronze Age or Iron Age that conditions became intolerable. The various activities of man, intentional or incidental, will now be considered from the standpoint of their effect on site fertility.

First of all, assuming that at one time there was high forest, the reduction of this to a single-layer community, however achieved, would tend to decrease base status, as already suggested. At first sight this seems to contradict the conclusions drawn from comparisons of rates of soil development in the prairies and under forest (Rost and Alway, 93), in which prairie soils were found to be less degraded than forest soils developed from the same material. However, the crux of the matter is whether the plant roots can reach a base reserve in the soil. On

these poor sites a grass vegetation may have been unable to do so, whereas the investigations in the prairies have been made on soils in which the grass roots should have had easy access to exchangeable calcium.

The means of forest destruction, presumably either fire or grazing (or both combined) would be important in bringing about deterioration of the soil. Though short-term investigations into the effects of fire on soil fertility are often inconclusive (Duchaufour, 40; Austin and Baisinger, 3; Suman and Halls, 106) there can be little doubt that when fire occurs regularly over a long period of time it must result in considerable wastage of the nutrient capital of the site (1), as well as having an adverse effect on the soil structure. The latter property may also be unfavourably affected by grazing animals, particularly if domesticated and therefore concentrated. We do not know to what extent tree-felling took place in these regions of Britain, but it is unlikely to have been divorced from burning. Any opening of the canopy would encourage such species as *Pteridium* and so greatly increase the fire hazard.

A more settled agriculture—even though no more than shifting cultivation—would introduce new dangers to the soil. The tilling of the soil, so exposing it to the weather, would aggravate leaching, and such primitive ploughing as may have been carried out (Hatt, 57) would be inadequate to turn the soil and counteract this effect. Crops would be grown and removed until the yield fell; that is, until the level of some plant nutrients had been still further reduced.

The direct effect of every one of these practices is to reduce the soil fertility; it is unfortunate that the indirect effect is usually the same. The destruction of the woody vegetation would not only result directly in a drop in base status, but at the same time remove the type of flora that could have kept it up. It is frequently the case (though not invariably) that the more tolerant a species is of poor soils, the lower is its potentiality for improving those soils. This is generally true of the Ericaceae, and of *Calluna* in particular. Its ultimate dominance, whether or not the result of climatic deterioration, would clinch the fate of the soil in three ways: by facilitating repeated accidental (or deliberate) burning; by the intense competition it offers to other species; and by its own litter, which aggravates soil degradation still further. Even though we have exonerated *Calluna* from responsibility for the onset of soil deterioration, it is likely that it is very largely responsible for the present-day sterility of our heathlands, and it has been shown to have an adverse effect on tree growth (119). *Pteridium* can also be condemned on at least two of these counts, and it has featured strongly in some of the pollen spectra (e.g. Crowthorne, Chick's Hill Barrow).

VII. DISCUSSION OF SOIL DEGRADATION

In this section some attempt must first be made to see how the soil relationships described here fit into the broad pattern of soil types from the North Temperate Zone. It is logical to start with the brown soils, believed to be the forerunners of the degraded soils which are now so widespread.

In the field during the course of this work the distinction between a soil with a bleached layer (A_2) and one in which iron was obviously present right up to

the surface has been the first and obvious criterion of difference, and indeed very few intermediates have been seen, perhaps reflecting the rapid transition from one to the other. Consequently, all unbleached soils have been classified as brown soils in the first instance. Looking at these soils more critically, however, it is seen that they may fall into more than one recognized soil type. The true brown earth or brown forest soil is probably only represented by Burley Oak, and even this is showing signs of recent degeneration in the accumulation of raw humus and the appearance of a micropodzol where *Fagus* is dominant. It must be made clear here that this is a brown forest soil in the sense of the *sol brun acide* of Duchaufour and not implying, as American terminology does, that it is a circumneutral, base-rich soil. In absolute terms of fertility, compared with agricultural land of high productivity, any natural soil developed on such base-poor parent material must be of low fertility, though in turn no doubt a good deal more fertile than its podzolized derivative.

Other brown soils described in this paper perhaps fit more into Duchaufour's *sols bruns lessivés*, because they show, particularly after ignition, some removal of iron from the A horizon and its accumulation in a diffuse B horizon. It is reasonable to assume that this results from the *lessivage* of clay, with which iron is associated; it does not involve podzolization. Examples of such soils are Matley Wood and the buried soil of Bickley Moor Barrow. Both these soils have been cultivated, but this does not prove that the process of lessivation has any connexion with such land use. It is interesting, however, that Dudal (44) found a *sol brun lessivé* beneath a Roman tumulus in Belgium and concluded that leaching could have started under cultivation.

Most of the observations reported here would agree with the view put forward by Duchaufour (39) for the Atlantic zone of France, that the climax soil on a wide range of parent materials was a brown forest soil. The brown soils on the poorer materials, however, may degrade more or less rapidly, even under oak forest, though Duchaufour maintains that man's influence is only to speed up an existing process. Subsequently (41), he has put forward a genetic series to show the stages of deterioration of acid soils resulting in the end-point, the podzol.

Sol brun lessivé	—	*sol très lessivé*	—	*sol podzolique*
(*Chênaie à mull*)		(*chênaie dégradée*)		(*lande sèche*)

Similar series have also been devised for American soils; Stobbe (105), for instance, suggests the following dynamic sequence:

Brown forest→grey-brown podzolic→brown podzolic→podzol.

Allowing for differences in terminology (Duchaufour equates grey-brown podzolic soils with *sols lessivés*) there is clearly a close parallel between the two schemes. Lyford (69), however, while agreeing that there are such genetical relationships among the podzolic soils, maintains that some groups, especially the podzols themselves, are polygenetic. His evidence shows that transitions may involve thousands of years.

There are many references in the literature to acidic brown soils. McCaleb and Lee (70) prefer the term 'acid brown forest soils' to 'grey-brown podzolic soils' as more nearly expressing the nature of such soils in North Carolina. Tedrow and Hill (112) and Drew and Tedrow (38) describe brown soils under arctic heath with surface pH values ranging from 3·5 to neutral. Within the forest zone in

Alaska, Kellogg and Nygard (63) encountered sub-arctic brown forest soils which appeared stable, although they could podzolize. The map produced by these authors interestingly shows the main areas of podzolization to be within range of the main settlements, while the brown forest soils were apparently in the less accessible areas. In Ireland it has been observed that podzolization has resulted from land use following Neolithic settlement and Evans (48) stresses that such changes cannot be accepted as proof of climatic change. In Vesterålen, Norway, Lothe (68) invoked climatic differences to account for the occurrence of brown soils above 350 m. and podzols at a lower altitude. (It is interesting to note that these brown soils were more acid than the podzols.) Such an altitudinal zonation is not usual in the northern regions, and barring geological differences, past land-use seems, on the face of it, a more likely explanation.

The term 'podzol', originally based purely on morphology, now implies certain process mechanisms too, and this change in meaning has resulted in much confusion. While clear examples of podzol, such as the heath podzol of north-west Europe or the forest podzol of the Boreal zone, are easily included, difficulties arise over such soils as those described by Wilde, Voigt, and Pierce (122) on calcareous materials and with nearly neutral raw humus. These may be similar to the grey wooded soils of North America, which themselves were once classified as podzols, but which are characterized by high pH values. For example, Moss and Arnaud (74) found a pH range of 5·5 to 6·9 in the A_2 horizon.

The grey wooded soils and other iron-leached soils of high base status serve to remind us of two things: firstly, that iron-leaching is not of itself an indication of high acidity; and, secondly, that an iron-leached soil may have a high fertility. Subsequent leaching may lead to a fall in fertility without much visible change in the soil profile. It follows that the descriptive methods relied on in this investigation cannot alone give any reliable estimate of fertility.

It has already been said that Duchaufour equates the American grey-brown podzolic soil with his *sol lessivé*; in other words, he regards this soil type as the result of lessivation or downward movement of clay rather than of podzolization as the American term implies. Stobbe has pertinently pointed out that these soils are able to podzolize in their upper layers, so they could not have been formed by podzolization in the first place. It seems quite clear that the movement of iron can begin at an early stage and that this is not necessarily an indication of podzolization. Lamberts and Livens (65) have described loess loam soils in Belgium in which iron starts to move even before decalcification is complete and Stobbe has made the same point in relation to the grey-brown podzolics of Canada. The *sol brun lessivé* of Duchaufour, therefore, though showing iron eluviation, is not podzolizing, and we must ask whether its transition to a podzol is inevitable, or whether the change in soil-forming processes which would be involved is triggered off by some change in the environment.

Sites such as Keston and possibly High Rocks give support to the view that the sequence to a podzol is inevitable, since podzolization has apparently taken place under primary forest where there is no evidence of human influence; in general, however, soil degradation must be seen as a direct result of man's influence, and the question is simply, 'Is a new process being initiated or is an existing process being speeded up?'

Let us look at the time factor. A certain amount of evidence is available from

widely different sources about the rates of podzolization. This has been discussed by Jenny (60), who correlates the work of O. Tamm, Mattson, and Aaltonen. These workers, working independently, would all agree that a mature podzol takes 1,500 to 3,000 years to develop. Burges and Drover (9) found that the podzol profile was still developing at about 4,000 years, and they showed that iron movement was not recognizable until the soil was over 200 years old. Dickson and Crocker (23) also obtained figures of the same order for the maturation of a podzol in California. Chandler (13) found only very slight podzolization in material which had been exposed by the retreat of the Mendenhall glacier 250 years ago.

The inherent consistency of these data suggests that no great error would be introduced by applying them to British conditions. If it is taken, as a round figure, that the parent material of our present soils was first stabilized about 10,000 B.C. either by the retreat of the ice or the cessation of periglacial conditions, and allowing for a millennium or two of cool climate before the Post-glacial warm periods developed, it is apparent that podzol soils, if they were developing, would have reached maturity long before the Bronze Age. Yet in no case (except possibly Portesham) was there a soil under a Bronze Age barrow which one could describe as fully developed. In other words, these soils were not the result of gradual transition through *sols lessivés* to podzols, but podzolization had set in very much later, apparently as a response to environmental change.

It may be argued that though buried soils such as that of Chick's Hill Barrow were not fully enough developed to represent continual podzolization through the Post-glacial, yet they were too well-developed to have developed merely since the forest was cleared. Kittredge (64) points out that, while slow rates of podzolization are usual in undisturbed forest, there are authenticated cases of podzolization taking place in less than 20 years. He attributes this to artificial factors such as severe thinning, or the introduction of conifers outside their natural range. Nemec (76) reports repodzolization of ploughed-up heathlands under conifers in about 15 years. Another relatively rapid case is that of abandoned fields, podzolizing under White Pine, as described by Griffith, Hartwell, and Shaw (55).

This investigation has shown that topsoil material—material from prehistoric culture soils—podzolizes much more rapidly than subsoil parent material. In some way this topsoil seems to have become predisposed to podzolization. The evidence from the barrows of the Tabular Hills in particular indicates that this was a rapid process superimposed on the older process of lessivation (cf. Bickley Moor Barrow). At Goodland, too, the thin iron-pan soil was shown by Proudfoot to be superimposed on an older soil in which iron was accumulating at a lower level, and this thin iron-pan soil must have been formed in a relatively short space of time. Present-day soils of this type are known to have formed in 100 years or so (Proudfoot, 85; Crompton, 18).

So far the terms 'podzolization' and 'degradation' have been used to describe the formation of a bleached layer by the removal of iron from the upper layers independently of clay movement. It must be recognized, however, that the processes involved may not always be the same, although it has to be admitted that our knowledge of the processes is still slight. The removal of iron by true

podzolization has already been described, and this doubtless applies to the humus–iron and humus–gley podzols of the New Forest and Dorset, on materials which are freely draining at the surface and under low rainfall. The thin iron-pan soils of the north have, however, been described as a separate type, sometimes called 'peaty gley podzols'. It has been said (Crompton, 18) that they are formed under conditions of higher rainfall where surface waterlogging can take place due to a peat layer or a grass root-mat, which in turn brings about the removal of iron by gleying rather than by podzolization. One can see that this explanation might apply to the Cleveland watershed and to Winter Hill, where there is a higher rainfall (over 40 in.) and where the thin iron-pan soils readily give way to peaty gleys on heavier material. Moreover, the prehistoric evidence is that grassy clearings were created within the forest and since there was no cultivation a grass root-mat could easily have been formed.

There are certain difficulties in accepting this explanation for the thin iron-pan soils of the Tabular Hills, In the first place the rainfall (32 in.) is not so high today. It may, however, have been higher in the Bronze Age, for Brooks (7) suggests that the prevailing winds were then from the North Sea. It will be remembered also, that *Alnus* was an important species in the forest phase of both the Cleveland Hills and the Tabular Hills, in contrast to the southern sites, and this might indicate wetter conditions. Nevertheless, these upland heaths today show no signs of peat formation, though there may be water standing on the surface during the winter. In prehistoric times the land was in cultivation and as long as this persisted the necessary surface waterlogging would not occur. It is perhaps significant that, of the three barrows examined on the high moors, two had indurated iron-pans and the other a peaty gley soil, while of the five examined on the Tabular Hills only one had an iron-pan and this was weakly developed.

Historically and ecologically there is no clear distinction between the heaths of the Tabular Hills and of southern England, and this suggests that the soils should be related. Crompton points out that it has been suggested that some thin iron-pan soils are merely podzols that have formed where the B horizon has been unable to develop normally. In other words, the thin iron-pan soils may be polygenetic, with different processes producing a similar end-point. The tendency of the iron-pan to pick out old interfaces is characteristic of these soils (Reasty Top Barrow, Suffield Moor—Birch), and the prehistoric soils give no support to the theory put forward by Crompton that the thin iron-pans gradually move downwards. In the Tabular Hills, at any rate, the full depth of leaching is quickly established, and the iron-pan forms at the base of the A_2 at the same depth as in the present soil.

The factors which determine the level of pan formation are probably a mixture of biological, chemical, and physical. Deb (22) found it necessary to postulate some microbiological mechanism to account for the precipitation of iron, but it does not follow at all that an iron-pan will form where the iron is thrown out of solution. It has been shown by a simple experiment that the physical structure of the material can determine where accumulation will take place. A column of non-calcareous crushed quartz gravel (from Doncaster) was constructed in layers of increasing particle size, the largest at the top. Through this column a flocculated suspension of ferric hydroxide was circulated for 14 days.

Iron deposition occurred at the two lowest interfaces, the upper one continuing to develop while the lower soon became 'fossilized'. Where flow had taken place down a particular channel its course was outlined by diffuse iron deposition. It is apparent that where the rate of flow is restricted, as at an interface or at the edge of a channel of freer drainage, deposition will take place. Since the suspension was at all times flocculated, it follows that deposition is not directly correlated with precipitation. This principle is frequently applicable in the field. Fitzpatrick (49) has observed the formation of iron-pan at an indurated horizon caused by periglacial conditions and stratified sands frequently show a series of pans (Plate I, 1). The picking out of artificially compacted surfaces beneath barrows was described by Fox (51, 52), and solid objects or layers in the soil may become coated with iron-pan. Among the sites described here iron-pans were seen at interfaces at Reasty Top Barrow and Suffield Moor—Birch, where the interfaces were demonstrated palynologically. Not infrequently a thin iron-pan may be found within a broader zone of iron deposition where there has clearly been a surface effect (e.g. Lyndhurst—The Ridge, buried soil).

The complex configuration of a B horizon is frequently determined by the course of drainage channels through the soil; such drainage channels may be due to periglacial conditions (25), to old root systems (Plate I, 1), or to similar irregularities. Such a configuration is in itself sufficient to indicate the dangers of assessing the age of a heath podzol merely from the eluvial depth. Indeed it seems unlikely that the heath podzols gradually increase their depth with age, as was postulated by O. Tamm (109) for the Swedish forest podzols. The eluvial depth is often predetermined and the removal of iron occurs relatively rapidly throughout the whole zone.

Comparisons between prehistoric soils and their present-day counterparts have shown that the best guide to the age of a podzol is the degree of development of the B horizon, though here, too, much variation may be found in the mature condition. This point has already been touched upon, but there are other aspects of the question which arise from the literature. Scheys, Dudal, and Baeyens (97) believe that podzolization takes place in two phases; first a forest phase results in the deposition of a friable ferric deposit and this is followed under heath by the deposition of a heavy compact humus layer. A similar concept was put forward by Burges and Drover (9), who found that the oldest soils in their Woy Woy series were humus podzols, the intermediate ones being iron podzols. These were associated with two different species of *Angophora*, but the authors also suggested that their findings accorded with Mattson's view that a higher pH would tend to lead to the formation of an iron-pan and a lower one to a humus-pan. However, in the present research it was found that the humus podzols of the New Forest were a good deal less acid than the thin iron-pan soils of north-east Yorkshire, which usually had no B_H horizon. In the prehistoric soils the humus accumulation layer was only developed weakly or not at all; on the other hand, though the degree of bleaching might be considerable, neither was there a good development of the iron-pan, at any rate, at low altitude. C. O. Tamm (108) has observed that soils buried for 100–300 years contrast with normal soils in lacking the brown colour in the B_1 horizon, from which he concludes that the deep humus is unstable and disappears if the supply from above ceases. This theory however, is not supported by the facts emerging from the present investigation.

The profile of Lyndhurst—The Ridge shows a massive B_H horizon, even though it has been buried for over 650 years, and by a much greater depth of soil than Tamm's sites. The Bronze Age soil under Chick's Hill Barrow shows humus accumulation still present after more than 2,500 years.

The correlation is clearly not with time alone, yet it does appear that humus deposition only occurs after considerable leaching of iron and the beginning of iron accumulation. It cannot be said with certainty that the movements of iron and humus are two separate processes, but their accumulation in the B horizon appears to be independent. Since the humus is usually deposited above the iron layer its deposition might be dependent on a change of pore-space in the B horizon as a result of iron (and possibly clay) accumulation. In the thin iron-pan soils, however, there is little humus accumulation in spite of the development of an iron-pan. In materials that have already been depleted of iron, such as the topsoil mounds of Chick's Hill Barrow, Springwood Barrow, and the rampart of Keston Camp, the profile that develops is a podzol with a massive humus accumulation zone. Again there is the suggestion that humic accumulation is in some way connected with a reduction in the amount of movable iron in the soil. These observations are in no way conclusive, but they would support a hypothesis that the type of profile developed is determined by the nature of the mineral material, particularly its content of movable iron.

By whatever process an iron-pan is produced, there is no doubt that it is a barrier both to water movement (Rennie, 88) and to root penetration (29). This in itself must result in a real decrease of fertility, since the subsoil becomes sealed off from root action, and even tree roots cannot easily penetrate it. The same may be true of the B_H horizon of a humus–iron podzol; for instance, the Lyndhurst—White Moor soil is extremely compacted at this level. In this respect a heath podzol may differ from a forest podzol, in which root penetration of the B horizon seems possible. In a peaty gley soil, of course, roots will not penetrate the subsoil because of lack of aeration. All these soils under heath, therefore, are soils that are virtually 'living on their humps', and this leads one to ask whether heathland is a continually deteriorating system; if so, what permanence is it likely to have? Again this is largely a matter of speculation, but there are indications that the climax status of heathland should not be assumed too readily. In the Cleveland Hills large areas of Callunetum, usually with raw humus or peat from 6 in. to 2 ft. thick, are rapidly eroding (Plate I, 4). Such erosion usually starts along a sheep walk or a track (old turf-sled tracks may show severe gullying, e.g. Plate I, 3). It is clear that where the vegetation is not continuous, or where run-off water is concentrated, there is danger of erosion. Doubtless this is associated with the poor structure and consequent impermeability of such soils. It is an interesting feature of this process that the extent of erosion may be aggravated by secondary wind conditions. Small whirlwinds may arise in hot, dry weather, presumably owing to heat differences between the dark humus and the exposed bleached horizon, and these may greatly extend the original scar. It may be argued that climatic conditions above the 1,000-ft. contour are not typical of heathland country in general, but it is also possible to regard such areas as being at an ecological stage that is being approached more slowly in the lowlands. Indeed, even lowland heaths can suffer in a similar manner; I have seen gullying on the Holterberg Heath in Holland as a result of

the disastrous storms of January 1953. This started along tracks in exactly the same way as it does at higher levels in the Cleveland Hills.

It is perhaps not irrelevant that the plant communities on deeper hill-peat (e.g. on the Pennines) are showing the same tendency to disintegrate. If the heath is to be regarded as a wasting system, how much more true is this of the deeper peat habitats, where organic matter and its contained plant nutrients are continually going out of circulation. Both hill-peat and heathland may be manifestations under different climatic conditions of a prolonged ecological imbalance. It will be remarkable if their courses eventually converge—at total erosion.

VIII. THE REGENERATION OF DEGRADED SOILS

THE processes of soil development dealt with so far have all been in the nature of degeneration, in the sense that they have proceeded progressively further and further from the soil type associated with the climax vegetation. The present soils are of a much lower level of fertility and we may even doubt their ultimate stability. It has been shown, however, that this process of degeneration can be halted and even reversed under certain ecological conditions (27).

Among the sites mentioned in the paper just quoted, two have been studied in further detail by pollen analysis, together with a third discovered more recently. Though the results modify the original conclusions they do not invalidate the general hypothesis (see also 33). The three sites all show the development of mull or mull-like organic matter in what has clearly been at one time the A horizon of a podzol. In each case the B horizon is still present, though it may be changing in character. The sites, of which fuller details are given in the Appendixes, are Pondhead, Suffield Moor—Birch, and Keston Copse.

Pondhead (Plates VI, 4 and VIII, 4). There was apparently a period when this site had been reclaimed as farmland from heath, prior to its planting up with oak and chestnut. It is unlikely that the land was arable during this period, since the pollen diagrams show no sign of disturbed sequences.

Suffield Moor—Birch (Plates V, 3, and VI, 2). There has clearly been a phase following the dominance of heath when the site was under grass, with which was associated a good deal of *Plantago*. It also appears likely that grass and weeds preceded the spread of heath and that some grasses formed a component of the heath flora. The amount of grass pollen in this soil points to a prolonged occupancy of the site by grasses, compared with which the dominance by *Betula* is brief. Again it seems unlikely that the site has been ploughed, since the pollen stratification is reasonably pronounced. Though the iron-pan was largely disintegrated and intermittent, what was left of it was all *in situ*; there was no evidence of its being displaced.

Keston Copse. The present tree cover (*Acer pseudoplatanus*, *Aesculus hippocastanum*, *Crataegus*) has left little trace in the pollen record, the pollen of these species being scarcely preserved. The pollen analyses were almost uniform at all levels and the frequency remained high. It appears that this was a thoroughly mixed soil down to a foot depth, which is deeper than ploughing would normally

go, though this possibility cannot be ruled out. There was abundant earthworm activity and vigorous rooting, and the pollen, though abundant, was highly corroded, indicating intense biological activity. There is thus no means of telling the relative sequence of the different pollen types, but the pollen spectrum has the components of the oak forest (cf. beneath the rampart) combined with a high proportion of grass pollen. Since the oak soil beneath the rampart was podzolized, the inference seems justified that the development of mull was due to a long phase of grass dominance. *Pteridium* was also abundantly represented, but it was unimportant in the Pondhead and Suffield sites.

Though all these three sites are at present under some form of deciduous woodland, the pollen analyses suggest that a grass phase has been of greater duration since the reclamation from heath, and it is clear that this phase must be taken into account in attributing the cause of the change from mor to mull formation. While it has been demonstrated that the effect of a birch crop is to decrease the acidity and increase the biological activity of soil, these changes appear to take place initially in the surface humus and the extension into the upper layers of the mineral soil seems to be a slow process. In these cases, where it is seen to have happened there is strong evidence of a grass phase having been an intermediary.

It should be stressed that for various reasons already mentioned, it is unlikely that these sites have been cultivated, with the possible exception of Keston Copse; it seems more probable that they have been converted into grassland from heath, for example, through the concentrated activity of grazing animals or some similar agency. Nor is there any evidence that the sites have been manured, limed, or marled, though it is true that if such were found to have occurred, most of the observations described here, and in particular those mentioned below, might be explained.

The adhesive tape profiles have revealed an unexpected and significant feature of these regenerating soils. In a normal heath podzol the ignited samples from the A_1 and A_2 layers show no iron coloration whatever; usually, however, there is a more or less strong yellow or orange colour development in the samples from the raw humus. These regenerated soils all show considerable iron coloration in the mineral soil throughout the zone of mull development. Whether it is due to the redistribution of an iron-rich organic layer through the agency of soil fauna, whether it is an effect of the vegetation, or whether it results from liming or marling, cannot be told from these observations alone. This condition, however, combined with the dissolution of the pan as a coherent layer in the Suffield profile, illustrates more vividly than any other feature the reversal of the process of podzolization and the onset of genesis towards a brown soil type. That this should have happened in the Keston soil is particularly interesting, since the soil associated with the undisturbed deciduous forest had been a podzol.

There is not a great deal of reference to podzol regeneration in the literature. The subject has already been discussed in an earlier paper (27), but certain specific references to grass as a medium of soil improvement have appeared since. Jacks (59) calls grass 'the best soil-improver known'. Of particular interest is the work of Sjörs (100, 101), who has made soil studies under forest and under meadows in sub-arctic Sweden. The general soil type on the non-calcareous parent materials of the region is an iron podzol with raw humus. Under meadow the raw humus layers have been converted into mull, which incorporates part of

the old A_2 horizon. Below this the iron podzol remains morphologically unchanged. These meadows are grazed moderately and cut for hay in July, but they are not manured intentionally. Tamm (110) also refers to such hay meadows, mentioning the excellent soil condition. In the more rainy west of Sweden this practice was not in operation, and here forest clearings became heaths with attendant podzolization, as may have happened in prehistoric times in the wetter areas of Britain. Robinson, Hughes, and Roberts (89) stress the importance of grasses in maintaining a high status of organic matter in the soil and a better crumb structure than is found in podzols.

Agricultural practice, as is well known, may bring podzolized heath soils into production, particularly if heavy manuring can be undertaken. This has been described by Dobrzanski (37) for podzolized loess soils in Poland; some characteristic features of this change were decreased acidity, increased amount and depth of humus, increased nutrient status, and the disappearance of the eluvial/illuvial boundary.

The role of trees as soil-improvers has been less studied, probably owing to the slower rates of change that may be involved. Nevertheless, since my last summary, Burrichter (10) has published an important paper on the improvement of heath soils by deciduous trees, especially birch and oak, with particular reference to the organic matter and associated microflora. The effect of the deciduous trees in decreasing acidity, increasing the organic matter status, and encouraging the microflora is strikingly demonstrated.

However, just as there is a divergence of views about the tendency of deciduous trees to cause leaching of the soil, so there is a contradiction in the ability of podzolized soils to regenerate under deciduous forest cover. In discussing this contradiction, Neugebauer (77) points out that the simplest explanation would be that some sites have been limed or marled whereas others have not, but no confirmatory evidence is forthcoming.

So this question of humus regeneration, and thereby soil regeneration, must be left as a partly unanswered paradox. Handley (56) has shown that the litters of different species have different biological properties, some types favouring mull formation, others mor. The grasses nearly all fall into the former category, as far as we know at present. Yet we have seen that soil degeneration has taken place under grass in the past and it is even doing so today. However, this may be connected with the physical conditions produced by a grass mat, rather than with the biological processes of litter decomposition. In historical times, soil regeneration has also progressed most rapidly under grass. Robinson, Hughes, and Roberts, in the same paper in which they described the soil-improving qualities of grasses, also stated that 'land left for long periods under a poor grass cover is probably undergoing podzolization'. They point out that in recent years a more rapid turnover of the sheep flocks has probably resulted in a reduction in the base status of the soils, a loss not now remedied by liming, so favouring podzolization.

Soil genesis on the poor parent materials seems to be a two-way process, but so far the experience has been mostly in the adverse direction. We have seen less and know less of the upgrading processes. But it is against this background that man's efforts to turn the heaths and moors to his own use once again must be seen. Within the last century or two the afforestation of heathlands has been widely

undertaken, though only intensively in the last few decades. Expediency rather than ecology has dictated the use of coniferous species in these schemes, and as a result little improvement in the health of the soil has been brought about. It is true that exposure is replaced by shelter, and that burning is prevented, both factors of great ecological significance; but they are offset by the fact that we must take a crop off the land and so deplete further the already low nutrient level. The Forestry Commission has advocated the introduction of soil-improving species into the new forests once they have become established, species which themselves may have no productive value—though if they have, so much the better.

It is clearly beside the point to regard the majority of our heath podzols as potential forest soils, when the historical evidence clearly shows that they have greatly decreased in fertility since the deforestation of the land. Only in a few cases was the original forest soil a podzol, and that of a different fertility level from any heath soil. This soil degeneration will not be rectified merely by planting the heaths with trees and making believe that we have thereby established the forest/forest podzol complex, and this on land which may never have had a forest/forest podzol equilibrium (Plate V, 4). Our aim must be to restore the ecosystem to its original balance and to preserve it against adverse agencies. This does not imply a 'back-to-nature' policy, but an acceptance of the principles upon which stability depended. We may find it necessary, perhaps even economic, to use fertilizers to help bring into operation the regeneration process described in this section.

We must recognize that our bank account in soil fertility is heavily overdrawn and only some form of repayment stands between us and bankruptcy. It is a debt that has been incurred for us by many previous generations, but if we wish to preserve the land, let alone use it, we must make some effort to discharge the debt, even if we do it by putting so much down and paying the rest by easy stages.

IX. SUMMARY

In an attempt to elucidate the course of soil genesis on land which now carries heath, over thirty sites have been investigated, many of them archaeological sites of various ages. Present-day heathland soils and the soils buried beneath earthworks have been examined by pollen analysis and recorded by colour photography and other means.

It is concluded that though a few of the soils have been podzols since the Atlantic period, the majority are secondary, having arisen as a result of man's assault on the landscape, particularly in Bronze Age times. The causes of this change in the course of soil development, the onset of podzolization in what had previously been a brown forest soil, were examined as far as the evidence allowed. It became apparent that there was no absolute correlation with climate, nor was vegetation closely correlated, except in so far as change followed the destruction of the original woody vegetation. Parent material alone was a critical factor in only a few cases, but it was found that topsoil material which had been

subjected to prehistoric human influences was much more readily podzolized than subsoil.

The nature of the soil degradation and the complex of factors leading to it is discussed, but it is not possible on the evidence to give an estimate of the relative importance of these factors. It is pointed out that for stability to be restored, especially if it is proposed to crop such land, the depredations of the past must be made good and some attempt made to exclude those aspects of treatment that have in the past led to degradation. In particular, where soil regeneration is to be seen, it may be assumed that desirable biotic relationships are being re-established, and attention is drawn to the conditions under which such soil regeneration is found today.

X. CONCLUSION

THE processes of soil genesis are to be seen as determined by a complex set of factors comprising the five enumerated in the Introduction to this paper, but to which must be added the disturbance of the ecological equilibrium, particularly by man. This factor is in itself a complex of separate influences all acting in the same sense. Its effect has been so great on acid soils that it has overridden the other soil-forming factors and it is too great to be incorporated within their framework. Yet it is this factor that is often unrecognized or underestimated.

The use of heathland in the future may continue the loss of fertility which has been going on for so long, or it may check it, according to whether any attempt is made to restore an ecological equilibrium.

APPENDIXES

LIST OF SITES

I.	Bickley Moor	XVII.	Lun Rigg
II.	Bickley Moor Barrow	XVIII.	Lyndhurst—The Ridge
III.	Burley Barrow	XIX.	Lyndhurst—White Moor
IV.	Burley Heath	XX.	Matley Wood
V.	Burley Oak	XXI.	Oakhanger—The Warren
VI.	Burton Howes—Barrow 1A	XXII.	Pondhead
VII.	Burton Howes—Barrow 4D	XXIII.	Portesham
VIII.	Chick's Hill Barrow	XXIV.	Ralph Cross
IX.	Coldharbour	XXV.	Reasty Top Barrow
X.	Crowthorne	XXVI.	Springwood Barrow
XI.	Decoy Heath	XXVII.	Suffield Moor—Birch
XII.	Goodland	XXVIII.	Suffield Moor—Heath
XIII.	High Rocks	XXIX.	Suffield Moor—Pine
XIV.	Keston Camp	XXX.	Troutsdale
XV.	Keston Common	XXXI.	White Gill—Stony Rigg
XVI.	Keston Copse	XXXII.	Winter Hill Barrow

Note on the Pollen Diagrams

Each curve is double, the histogram on the left of the centre line indicating Absolute Pollen Frequencies (grains per gm. soil), that on the right indicating percentages (of total pollen plus fern spores).

The symbol associated with some Gramineae curves marks the occurrence of cereal pollen.

Site No. I. BICKLEY MOOR

Place

8½ miles WNW. of Scarborough, Yorks., N.R.

National grid reference

SE/904907.

Geology

Jurassic: Passage Beds of Middle Oolite. A non-calcareous coarse sand.

Topography

Level plateau site at 750 ft. O.D.

Present vegetation

Callunetum. Adjacent to pine plantations, 25 years old.

General

This site was studied to elucidate the line of charcoal lying at 19 in. depth, which had been revealed in a Forestry Commission soil pit, but since it is adjacent to Bickley Moor Barrow (Site II) it also serves for comparison with that site.

Pollen analysis

(*a*) *Buried level.* At 18 in. in the pollen profile there is clear indication of a buried level, shown by peak frequencies of *Corylus*, *Alnus*, and especially ferns (*Dryopteris* type). The light-demanding herbaceous species such as grasses, *Plantago*, and *Calluna* were virtually unrepresented.

This level approximately corresponds to the line of charcoal and burnt soil mentioned above. The charcoal was mainly of *Quercus* with a little *Corylus*. It is interesting that the pollen analyses show little *Quercus* pollen at any level; this is especially characteristic of the Yorkshire soils.

The 3 or 4 in. of soil covering the old surface contains mainly fern spores, thus resembling the analysis of the soil below the surface, from which the superimposed material probably originated.

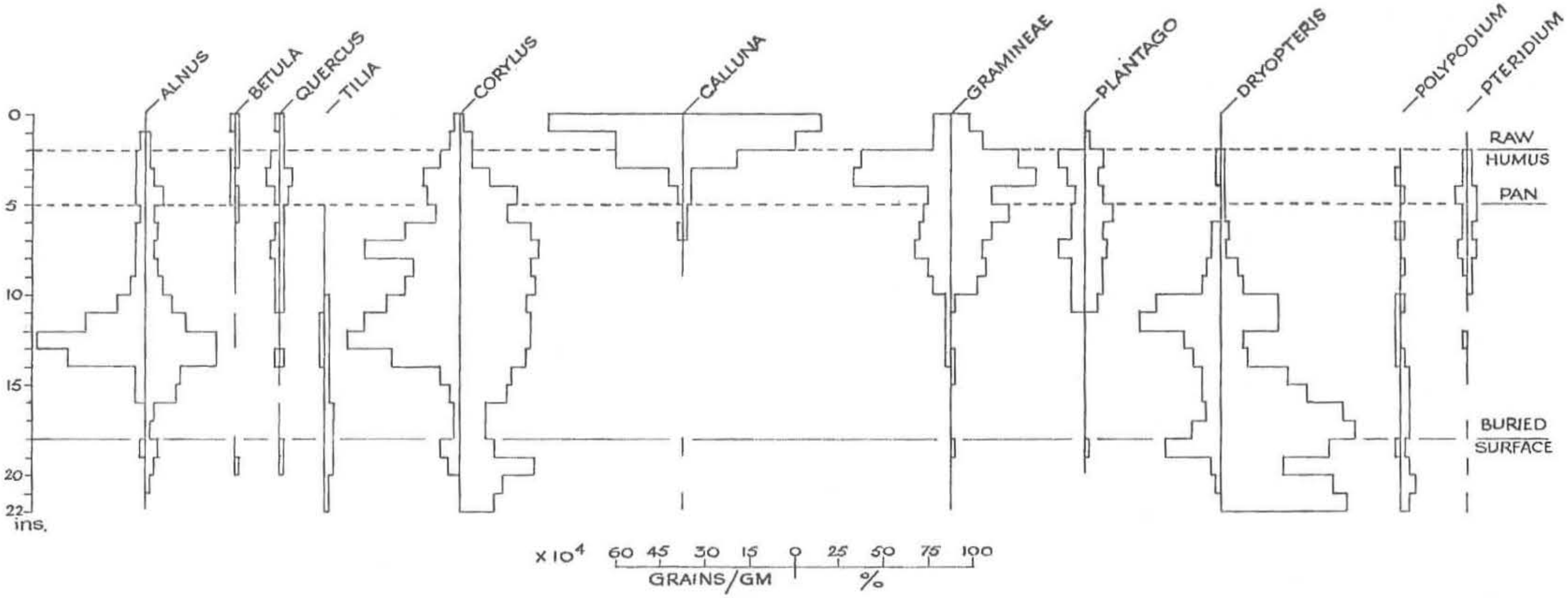
(*b*) *Later pollen.* The deepest pollen occurring at increased frequency (and therefore probably post-dating the buried surface) is of *Corylus* and *Alnus*. *Tilia* is also present at low percentage (continuing so right down through the buried surface). There is still an absence of grasses and associated weeds, and a total absence of heath species. *Alnus* then drops in relation to *Corylus*, but its fall is accompanied by a temporary boost in fern spores. Immediately afterwards grasses, *Plantago*, Ranunculaceae, *Cuscuta*, and Compositae appear, though *Corylus* remains predominant. *Pteridium*, another plant spreading in more open situations, also increases in proportion.

The diminution in the frequency and percentage of *Corylus* is accompanied by a big increase in the grasses and the appearance of *Calluna*. *Tilia* has ceased to be represented. The grass phase becomes more admixed with *Calluna* in the uppermost layers of the mineral soil, and in the raw humus the *Calluna* becomes predominant, with the grasses dropping abruptly. There is apparently a break in time between the pollen records of the base of the raw humus and the surface of the mineral soil.

The lack of influence exerted by the pan (indurated) on the pollen distribution points to its recency relative to the species whose pollen occurs at that level. This accords with the obvious conclusion to be drawn from the *Calluna* curve, which shows that this species is a relatively late arrival.

A sudden change in the grass and *Dryopteris* curves at 10 in. might suggest another

BICKLEY MOOR



(1)

buried surface, but this is not confirmed by the other pollen curves nor by the adhesive tape profile (see below).

Soil characteristics

0–1½ in.	Raw humus.
1½–5 in.	Dark-stained A_1/A_2 horizons; sandy silt.
5 in.	Indurated thin iron-pan.
5–10 in.	Orange sandy silt with faint fawn coloration.
10–19 in.	Orange sand.
19–20 in.	Zone of charcoal in brown loam; soil immediately below burnt red.
20 in.	Orange granular clay and grit stones; some reddened stones; charcoal flecks.

The 'hearth' was excavated beyond the confines of the original soil pit and was found to be of limited extent; it became diffuse in one direction and ended abruptly in another, varying in depth from 12 to 27 in. below the present surface. There has clearly been mass movement of soil material since the fire; some sort of solifluxion, leaving small sections of the burnt surface undisturbed, would seem to be the most likely answer.

The site was examined by an archaeologist, Mr. W. H. Lamplough, who could find no trace of artifacts; he was of the opinion that the phenomena observed were natural.

The A/T diagram emphasizes the intense leaching of the upper mineral layers and confirms that the buried level is only very weakly leached of iron. Humic staining from the present surface extends to 11 in., and from 13 to 20 in. there is also some discoloration removed by ignition. This may be partly due to comminuted charcoal. An unstained zone from 11 to 13 in. might suggest intruded material, but there is no closely corresponding break in the pollen analyses.

There is no confirmation of a possible unconformity at 10 in. (see pollen analysis).

Site No. II. BICKLEY MOOR BARROW

Place

8½ miles NWW. of Scarborough, Yorks., N.R.

National grid reference

SE/903906.

Geology

Jurassic: Passage Beds of Middle Oolite. A non-calcareous coarse sand.

Topography

Level plateau site at 750 ft. O.D.

Present vegetation

Callunetum, with some *Pteridium* on the mound. Adjacent to pine plantations, about 25 years old.

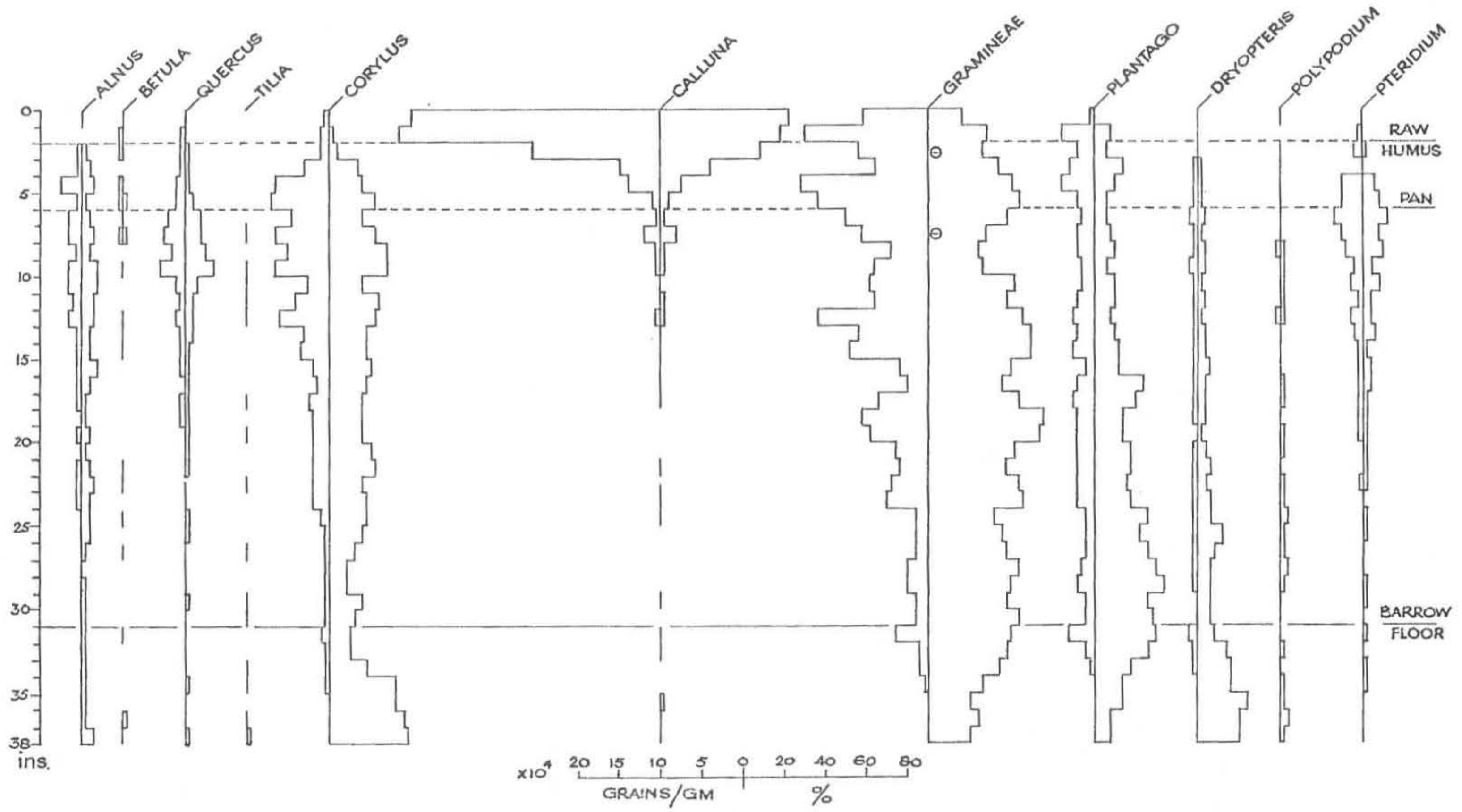
General

This barrow is unexcavated and so undated, but it is of Bronze Age type. It was used because the edge of it had already been cut away in the making of a forest road, exposing a section from which the old surface was readily accessible (Plate III, 1). The barrow lies about 100 yds. SW. of Site I.

Pollen analysis

Two profiles were taken, neither near the true centre of the mound. The first was a complete profile from the present surface through the buried soil; the second, nearer

BICKLEY MOOR BARROW
(COMPLETE SECTION)



(2)

the centre, was taken through a peculiarly stratified section of the mound, and was taken merely to locate the old surface, which could not be done with certainty visually.

(*a*) *Complete section.* The floor on which the barrow was built appears clearly at 31 in. in this section, shown by the increased frequency of a number of species, notably grasses, *Plantago*, and *Corylus*. Before the barrow was built *Corylus* and *Dryopteris* had yielded precedence to the grasses and weeds, with *Plantago* reaching remarkably high proportions.

The mound was built up of topsoil as indicated by the relatively high frequencies throughout. Probably the lowest 7 in. of the mound material came from this site or its immediate neighbourhood, but the much higher frequencies higher up suggest that the bulk of the soil was brought from elsewhere. The frequency curves, especially that of the Gramineae, show the characteristic peak and hollow sequence of made-up soil (cf. Chick's Hill Barrow).

Comparison with Site I renders it possible to attribute some approximate date to the main features of that profile. Clearly, the high *Dryopteris* and *Alnus* levels well precede this barrow in date, while the spread of *Calluna* post-dates it. *Tilia* is intermittently present in the old surface and this, together with the above-mentioned points, suggest that the barrow floor is chronologically equivalent to that part of the pollen spectrum of Site I which lies between 5 and 10 in.

It is difficult to interpret the vegetation sequence since the barrow was built, because pollen was already present in the soil. Three conditions might occur: (i) the pollen of a species formerly unrepresented will appear and will be readily recognizable as such (e.g. *Calluna*); (ii) the pollen of species present before will continue to be deposited and the curves will merge indistinguishably (e.g. probably Gramineae); (iii) no further pollen of certain species will be deposited and that already present will gradually be washed down from the surface, giving an increased frequency lower down (e.g. *Dryopteris*). The last two conditions render any interpretation very uncertain. Nevertheless, it is suggested that the peaks of *Quercus*, *Pteridium*, and perhaps *Alnus* between 5 and 10 in. seem large in comparison with the amount of pollen of those species present in the bulk of the mound. They may be regarded, therefore, as evidence of a period of forest regrowth after the mound was built, and before the spread of the *Calluna*. It is impossible to say, however, how the proportions of *Corylus*, Gramineae, and *Plantago* stood at that time. It may be significant that a similar increase in the three woodland plants, together with *Corylus*, is to be seen in the 3–5-in. regions of the profile from Site I before the spread of *Calluna*.

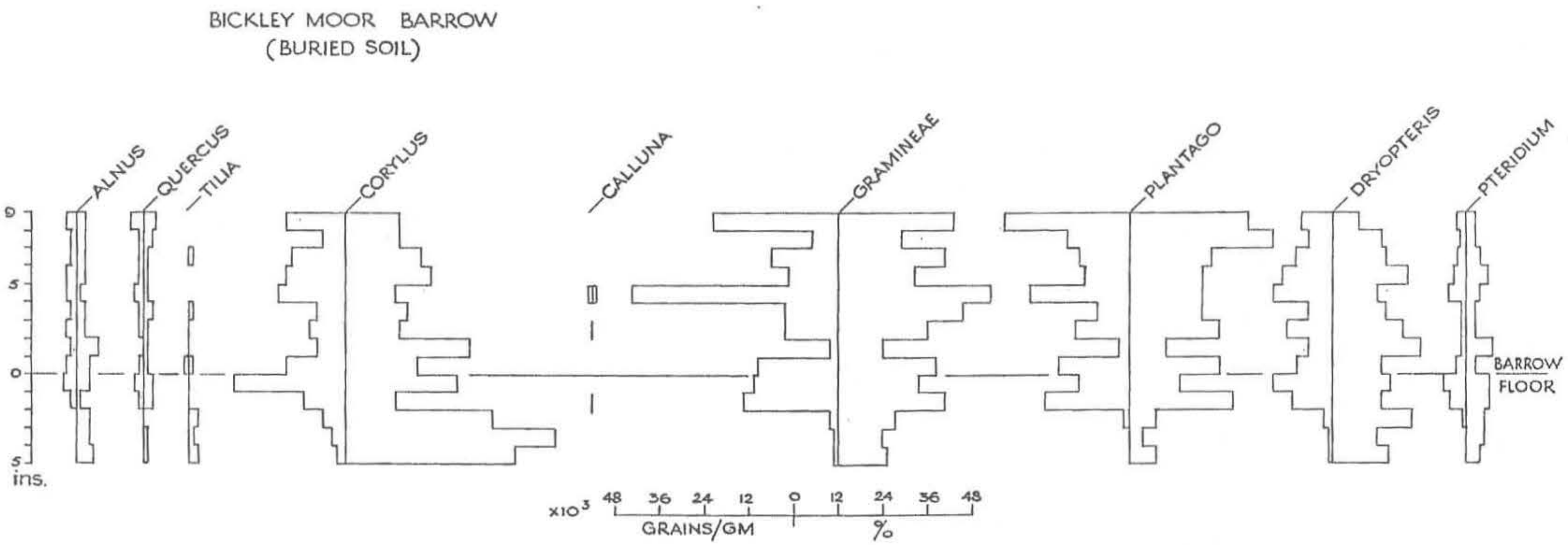
The overall comparison of these two sites suggests that pollen downwash is about twice as rapid in the barrow mound as in the undisturbed soil.

(*b*) *Buried soil.* This section also shows the characteristic irregularity of made-up soil above what is clearly the old floor, but below this the numbers of grains fall away steadily and characteristically. The section is remarkable for the narrow, dark bands about 3 in. apart, each dark-stained. These appear imperfectly in the A/T diagram, but it is apparent from the pollen analyses that they do not correspond with peak pollen values. They are not, therefore, to be regarded as turves but as secondarily stained horizons, probably interfaces.

The general pattern of the pollen spectrum at the old surface in the complete section is repeated with minor differences. Grasses and *Plantago* have spread at the expense of *Corylus*, though there is an increase in the *Corylus* percentage in the topmost inch. The fern spores are also relatively more abundant. Once again, the absence of *Calluna* is beyond question.

Soil characteristics

The characteristic thin iron-pan soil of the area passes over the barrow (Plate III, 1), bearing a striking similarity to the profile developed in the surrounding soil. This is the more remarkable in view of the conclusion reached above that pollen movement,


BICKLEY MOOR BARROW
(BURIED SOIL)
ALNUS
QUERCUS
TILIA
CORYLUS
CALLUNA
GRAMINEAE
PLANTAGO
DRYOPTERIS
PTERIDIUM
0
5
0
5
ins.
BARROW
FLOOR
x10³ 48 36 24 12 0 12 24 36 48
GRAINS/GM
%

(3)

and therefore, presumably, water movement, is more rapid in the mound than in the undisturbed soil.

The light band in the photograph lies above the true surface, which is indicated by the somewhat darker colour. As the dark line is the true surface, it is apparent that the original soil was scarcely bleached; the A/T diagram shows some intensification of iron colour in the ignited lowest samples, but in no sense can this be regarded as a podzol (Plate IV, 1). The second section of the buried soil alone, confirms this precisely.

It is typical of such buried soils that the amount of visible humus is small, though often detectable, contrasting with the buried podzols (e.g. Burley Barrow), which show a clear humus A_0/A_1.

Site No. III. BURLEY BARROW

Place

On the S. edge of Berry Wood, 1½ miles N. of Burley, New Forest, Hants.

National grid reference

SU/212052.

Geology

Eocene: Barton Sand, with slight hill-wash of Plateau Gravel.

Topography

On gentle S. to SW. slope; altitude 250 ft. O.D.

Present vegetation

Barrow covered by dense *Pteridium*, and with *Ilex* tree growing on the mound. The barrow lies on an ecotone with *Pteridium* dominant to the N. and *Calluna* to the S.

General

This is one of two small, round barrows. It has yielded remains from the Late Bronze Age. The barrow had been a rabbit warren and was much disturbed.

Pollen analysis

This has proved to be one of the most interesting analyses carried out, particularly as regards the structure of the mound. Samples were taken from the top of the mound right down to the buried subsoil.

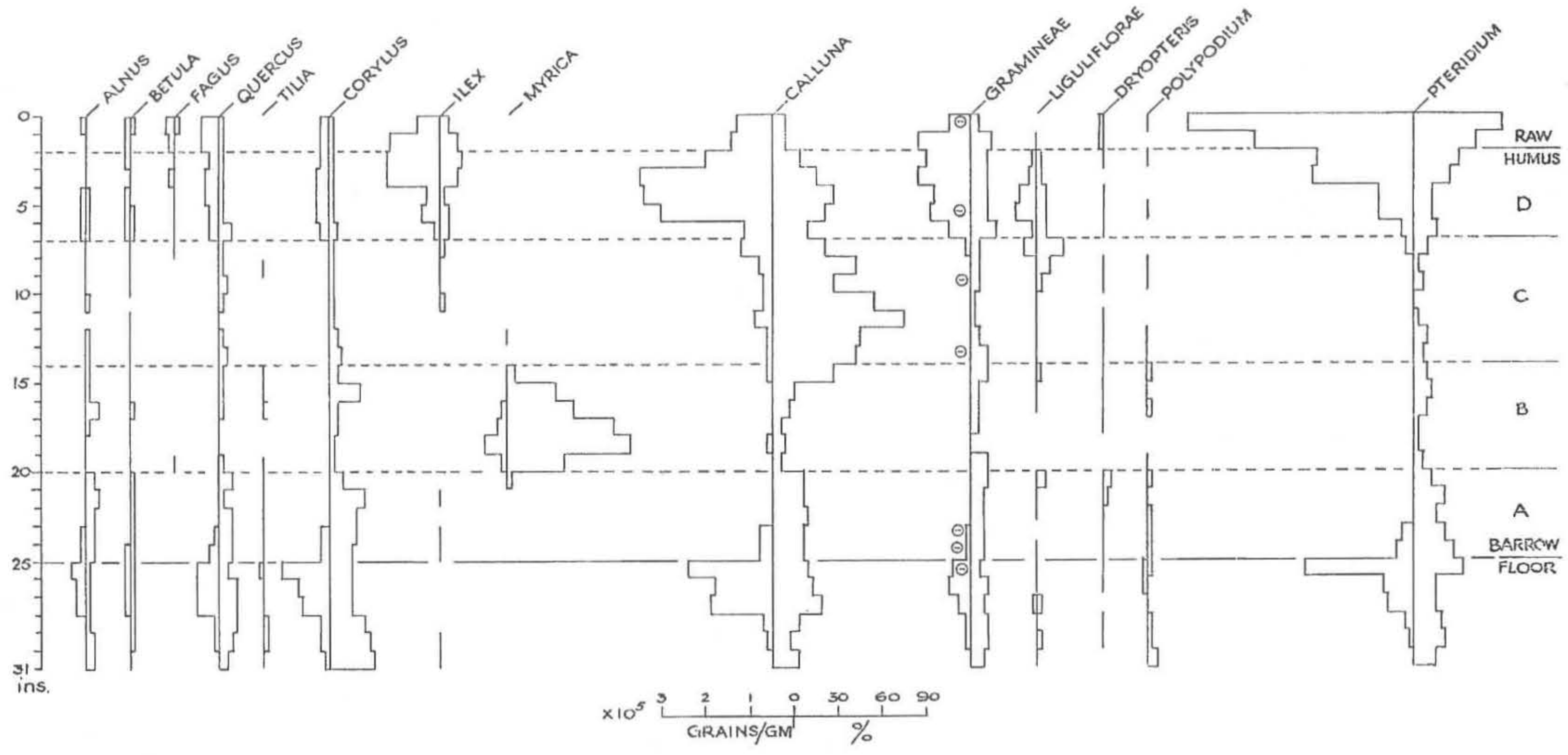
The old floor of the barrow is clearly identified with the 25-in. level, which coincides with the top of the dark humic horizon. The vegetation at the time the barrow was built was *Calluna* and *Pteridium*, the latter having recently become the more important. Before the spread of *Calluna*, *Corylus* had been predominant, with some *Alnus*, and also *Quercus*. A subsidiary peak of *Pteridium* coincided with this phase. *Tilia* was consistently present in small proportion.

The Gramineae and associated weeds did not figure largely, and although cereal pollen was found at the old surface, it is unlikely that this site was itself cultivated.

The material of the mound falls into four clear-cut layers of roughly equal thickness, labelled on the graph A–D, separable by their pollen spectra.

The lowest, A, is clearly a rough inversion of the undisturbed soil beneath, and has presumably come from the surrounding ditch. It is sharply differentiated from layer B, which has a high percentage of *Myrica* pollen and very little else. This material must have come from elsewhere since there is no ground suitable for the growth of *Myrica* in the immediate vicinity. The nearest boggy ground is 200–300 yds. away. Layer C is sharply differentiated by having no *Myrica*, but a high percentage of *Calluna*, though at low frequency. Finally, layer D, in which the pollen from the barrow surface

BURLEY BARROW



(4)

has accumulated, is recognizable by the high frequencies of a number of species. It seems likely, though difficult to prove, that this material was initially pollen-poor (cf. the low percentages of *Corylus*) and therefore probably subsoil material; in fact it is still relatively iron-rich. The bulk of this pollen may, therefore, be regarded as subsequent to the construction of the barrow. If this is so, a simple succession is discernible. Initially the mound was covered with *Calluna*, mixed with grasses, some Liguliflorae, and *Pteridium*. At this stage woody species were a little more conspicuous, but they soon dwindled in proportion. The *Calluna* gradually achieved complete dominance, though grasses persisted in smaller proportion. Even today *Molinia* forms a characteristic component of the local heath flora, and is temporarily dominant after fire (see Burley Heath—Site IV). Then came a period when *Pteridium* gradually increased again, together with *Ilex*, and we are probably seeing here a swing of the *Pteridium*/*Calluna* ecotone as local factors vary. In the raw humus at the surface we see the recent spread of *Pteridium* at the expense of the *Ilex*, a fact doubtless correlated with the gradual demise of the *Ilex* trees on and near the site.

A further point, perhaps more of archaeological interest than otherwise, is revealed by the Liguliflorae curve. It would seem to be more than coincidence that at each boundary between the four layers the percentages for this group show a sudden increase; this is even more clearly shown in the absolute frequencies, and since the scale of the graph is too small to show these changes, the following table is given.

A–B		*B–C*		*C–D*	
Depth (in.)	*Liguliflorae APF*	*Depth (in.)*	*Liguliflorae APF*	*Depth (in.)*	*Liguliflorae APF*
19–20	..	13–14	50	6–7	10920
20–21	1170	14–15	450	7–8	34320
21–22	80	15–16	30	8–9	4060

This might be due to a period of weed growth between each layer, and suggests that the barrow was built in phases, with a pause between each long enough to permit a weed flora to establish itself and flower. It is difficult to detect the same effect in other weeds, though in some cases it may be present though obscured. The *Varia* counts, however, also show it very clearly; these are pollen types that have not been identified, and in view of our experience they must be regarded as plants not normally components of the acid-tolerant flora. An interesting speculation springs to mind that the Liguliflorae and the *Varia* may represent floral tributes with which the mound was dressed at the completion of each stage. This explanation would overcome the objection of archaeologists to the implication of the alternative hypothesis that the construction of such a small mound extended over a number of years. It would be interesting to pursue the identification of the *Varia* to see if they have conspicuous flowers, but this is a side issue which time forbids me to follow up.

Soil characteristics

There are two levels here at which the soil profile is of interest. In the first place the buried profile of Late Bronze Age date shows up in strong contrast to the overlying material. The old surface falls at the top of the dark humic band which extends for 3 in. before passing over to 3–5 in. of intensively bleached sand (Plate VII, 3). We thus have the characteristic appearance of the A layers of a podzol. The B horizon, however, is scarcely developed, with very little humus accumulation and no obvious iron enrichment. The A/T ignited profile suggests, however, that there is some iron accumulation at 33–34 in. Below this the C horizon is somewhat clayey and shows some gleying, in which character it closely resembles that of Site IV, to which parallel reference should be made.

The material immediately overlying the buried surface shows patches of bleaching

and accords with the evidence of the pollen analyses that it has come from the immediate environs, probably from the ditch.

The ignition profile also provides some confirmation of the zonation of the mound as indicated by the pollen analyses. Layer C is particularly clear, having a deeper colour than the rest. The upper inch or two of this layer may have been enriched with iron from layer D, but this can hardly apply to the whole layer. There is a sharp division at each interface of the layer, separating off layer D and the upper face of layer B. The latter layer merges less suddenly into layer A, but it is clear that a transition does occur somewhere between 19 and 21 in.

It is remarkable that layer D is by no means a bleached layer. It is still quite rich in iron, though some accumulation may have taken place in the 5–7-in. zone. The natural A/T profile shows some humus accumulation in the 4–6-in. zone, and staining extends several inches beyond this. There are thus podzolic tendencies operating in this soil, but it cannot be termed a podzol yet. In fact it is little more than a degrading brown forest soil. This is most unexpected in view of the history of *Calluna* and *Pteridium* dominance on this mound: it is noted, however, that the material in which this profile has developed is apparently subsoil and not old topsoil.

SITE No. IV. BURLEY HEATH

Place

Open heath immediately S. of Berry Wood, and 1½ miles N. of Burley, New Forest, Hants.

National grid reference

SU/211051.

Geology

Eocene: Barton Sand with some superficial admixture of Plateau Gravel from above. The material becomes distinctly clayey in the subsoil.

Topography

On gentle slope to the SW.; altitude 230 ft. O.D.

Present vegetation

Calluna–Molinia heath.

General

This site serves for comparison with the buried soil beneath a near-by barrow (Site III).

Pollen analysis

Samples were analysed from the surface down to 18 in. and the results fall into three clear-cut zones. The top 8 in. show the development of heath from *Corylus* scrub, but there is nothing which clearly points to the time scale of this sequence; the consistent presence of *Tilia* from 1 to 6 in. might indicate that the process covered a very long time sequence. It is probable that there had been early cultivation on the site.

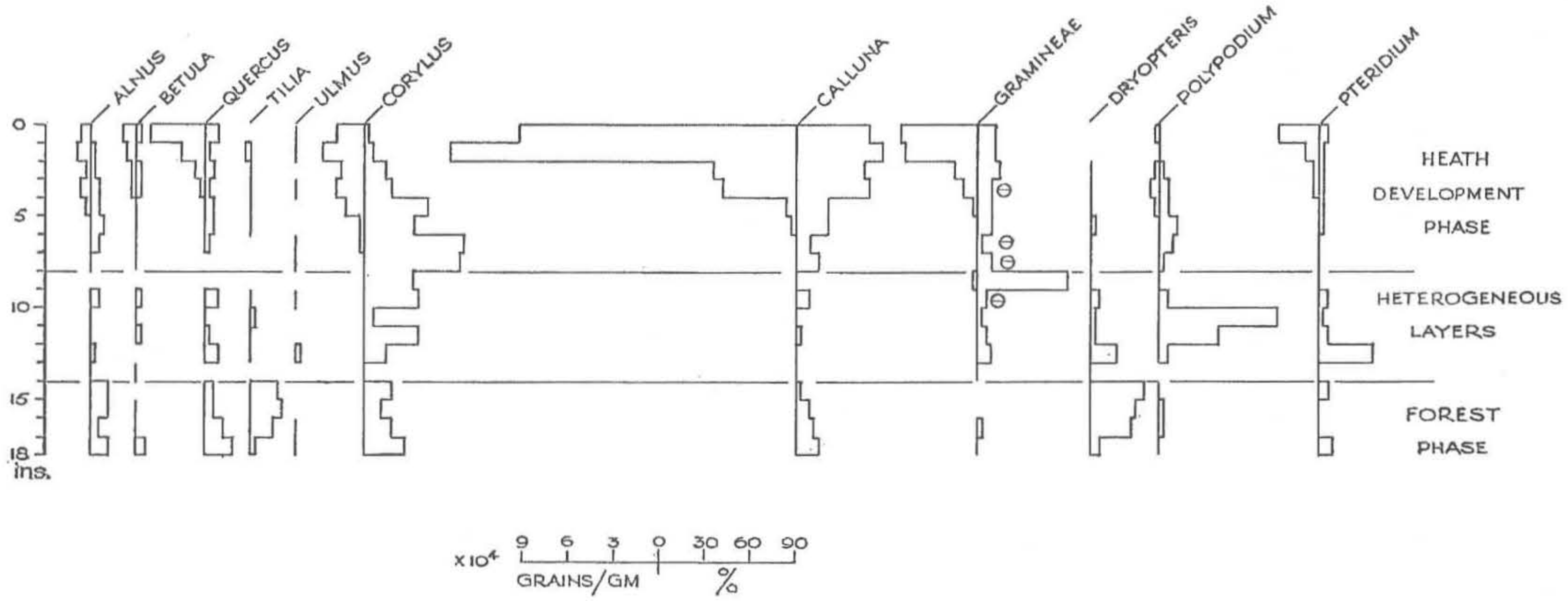
There is an abrupt change at 8 in., when grass pollen suddenly becomes dominant, showing greatly increased frequency as well as percentage. For the next 6 in. the spectra fluctuate wildly, until at 14 in. they settle down, with greatly increased frequency, to a pattern which clearly indicates forest conditions. *Tilia* and *Alnus* are the main tree pollens present, but *Corylus* is also abundant. There is a high proportion of *Dryopteris*.

This seems to be a complex example of a buried surface, the material between 8 and 14 in. itself being very heterogeneous, possibly due to some form of solifluxion.

Soil characteristics

The soil profile (Plate VII, 4) serves as a useful comparison with that under the

BURLEY HEATH (FULL PROFILE)



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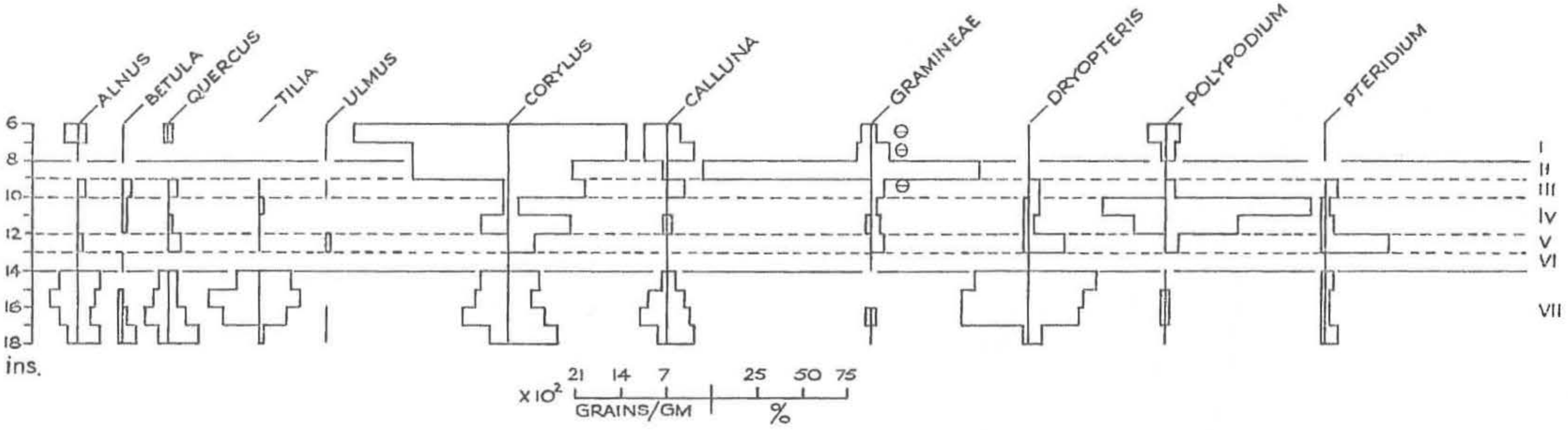
BURLEY HEATH (BURIED LEVELS)



I NORMAL POLLEN SEQUENCES FROM PRESENT SURFACE

II DOMINATED BY GRAMINEAE AND CORYLUS

III DOMINATED BY CORYLUS AND TREES

IV DOMINATED BY POLYPODIUM

V DOMINATED BY PTERIDIUM AND DRYOPTERIS

VI POLLEN ALMOST ABSENT

VII DOMINATED BY TREES, CORYLUS AND DRYOPTERIS

barrow (Site III). The surface raw humus is thin due either to burning or turbary; the profile in the mineral soil is rather deeper than in the Bronze Age soil, the bottom of the bleached layer lying at 7–10 in. in the barrow soil and at 10–12 in. in this profile. In view of the complexity revealed by the pollen analyses between 8 and 14 in. detailed comparison is not valid.

The big difference between the two soils comes in the B horizon, which in this case shows much more humus deposition (yet this is much less than some Barton Sand profiles show, cf. Site XVIII). The subsoil shows mottled gleying associated with the heavier texture of the material in this layer.

Site No. V. BURLEY OAK

Place

S. part of Berry Wood, 1½ miles N. of Burley, New Forest, Hants.

National grid reference

SU/213053.

Geology

Eocene: Barton Sand.

Topography

On a gentle S. slope; altitude 260 ft. O.D.

Present vegetation

Medium-aged *Quercus robur* with *Vaccinium myrtillus* ground flora.

General

This site serves as a basis of comparison with the other Burley sites, since it has an undifferentiated brown forest soil profile.

Pollen analysis

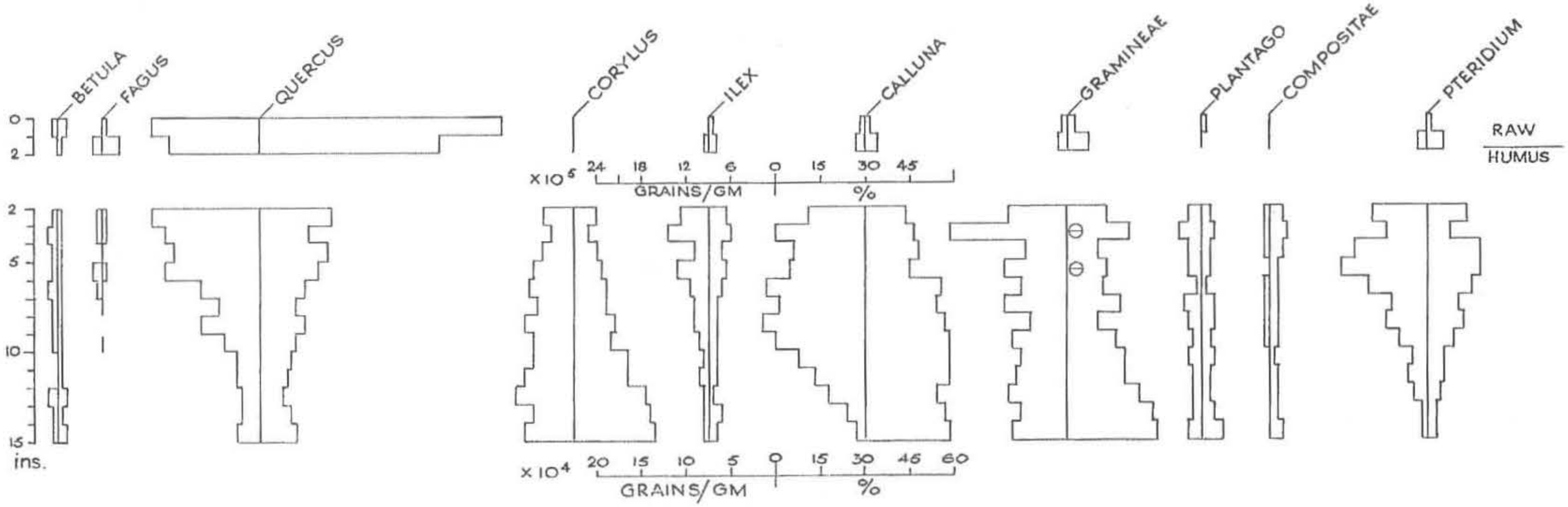
The earliest part of the pollen record shows a mixture of woody species, *Corylus* and *Quercus*, and plants of more open conditions—*Calluna*, Gramineae, and weeds. This suggests a mosaic of woodland and clearings. As time went on, *Corylus* and Gramineae gradually declined, whereas *Pteridium* spread, likewise *Quercus* and *Ilex*. Meanwhile *Calluna* remained unchanged in proportion, though probably only reaching complete dominance in patches. Eventually it fell away as *Quercus*, *Ilex*, and *Pteridium*, a woodland flora, spread. In the raw humus there is a marked contrast, in frequencies of course, but also in percentages. The light-demanding species have gone out completely and *Quercus* has reached supreme dominance. The exclusion of pollen of the species of open conditions may be brought about in two ways. The establishment of canopy will itself exclude the species from surviving on the site—at any rate in a flowering condition—and it will also reduce the amount of wind-carried pollen brought from adjacent open areas. These two effects will therefore work together. The presence of pollen of the light-demanding plants is therefore doubly indicative of relatively open conditions, though groves of woody plants and scattered trees may occur.

The absence of *Tilia* from this profile should be noted.

Soil characteristics

Underneath the thick raw humus there is a virtually unleached soil (Plate VI, 3), an acid brown forest soil. That such an undifferentiated soil should have persisted at all is in itself noteworthy, but that it has done so under ecological changes that in earlier times usually led to podzolization seems inexplicable. Such a profile, however,

BURLEY OAK



BETULA
FAGUS
QUERCUS
CORYLUS
ILEX
CALLUNA
GRAMINEAE
PLANTAGO
COMPOSITAE
PTERIDIUM
RAW
HUMUS
0
2
5
10
15
ins.
X 10⁵ 24 18 12 6 0 15 30 45
GRAINS/GM %
X 10⁴ 20 15 10 5 0 15 30 45 60
GRAINS/GM %

(7)

is not uncommon in this and similar woods, both on the sands and the gravels. In some cases, especially under *Fagus*, there is a micropodzol in the surface of the mineral soil, but there is no trace of that on this site, in spite of the ground flora of *Vaccinium myrtillus*.

Site No. VI. BURTON HOWES—BARROW 1A

Place

8 miles due S. of Guisborough, Yorks., N.R.

National grid reference

NZ/608033.

Geology

On the junction of the Grey Limestone series (non-calcareous) and Estuarine Beds of the Lower Oolite.

Topography

Hill-top site overlooking deep valley. Altitude 1,419 ft. O.D.

Present vegetation

Callunetum. Considerable moorland erosion in the vicinity.

General

This small turf barrow, one of a group, had been excavated the previous year and not yet restored. Though an undisturbed section through the mound to the subsoil was exposed, the surface was disturbed and overlain with spoil.

Pollen analysis

Two series of samples were taken, one from the present surface down into the mound, but falling short of the turf core; the other from the turf structure to the C horizon of the buried soil.

The series through the old surface shows two horizons, T1 and T2, which are rich in pollen and appear in the section as humic bands. It was assumed that T1 was the old soil surface and T2 the top layer of a turf. The pollen analysis, however, shows that T1 is directly connected with the superimposed samples and not with those beneath. It is apparent that these two humic bands represent the surfaces of inverted turves. Since there is no humic band corresponding in pollen spectrum with the soil profile, it must be assumed that this soil had had its upper layers removed before the construction of the mound.

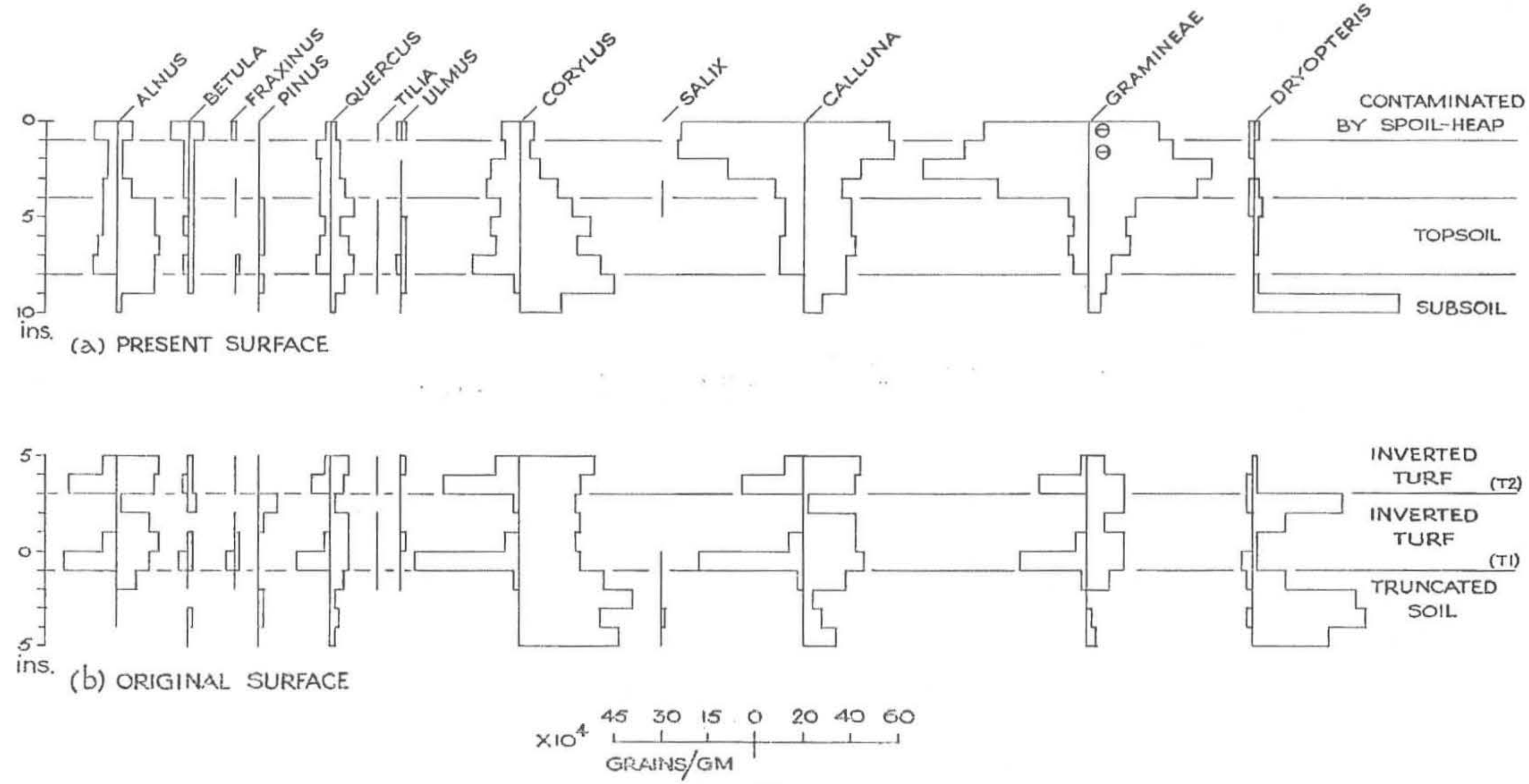
Even though their tree-pollen totals are separately inadequate statistically, the two humic bands show essentially the same tree-pollen spectrum:

	Alnus	*Betula*	*Fraxinus*	*Pinus*	*Quercus*	*Tilia*	*Ulmus*	*Corylus*	*NTP*	*ΣTP*
T1 .	50·9	9·1	9·1	+	30·9	+	+	101·8	178·2	55
T2 .	61·0	9·1	1·3	1·3	23·4	1·3	2·6	100·0	161·0	77
Mean	56·8	9·1	4·5	0·8	26·5	0·8	1·5	100·8	168·2	132

Comparison with the turves of mound 4D shows that the forest spectrum is the same in both cases, but they differ in the NTP percentage, which is considerably higher in this barrow. It may be taken, therefore, that of the two turf structures, that of 4D is the earlier. In this case the NTP percentage is sufficiently high to indicate extensive open areas, though still within a matrix of forest.

The second series of samples falls into three zones. The two lowermost samples are

BURTON HOWES – BARROW IA



poor in pollen and are probably subsoil in origin. Then comes a run of four samples which seem to be topsoil, showing relatively little change with depth. While it is not strictly justifiable to analyse the four samples together, nevertheless, if this is done the following spectrum emerges:

Alnus	*Betula*	*Fraxinus*	*Pinus*	*Quercus*	*Tilia*	*Ulmus*	*Corylus*	*NTP*	*ΣTP*
55·6	7·3	1·4	3·6	26·4	0·8	5·0	93·8	125·8	360

This is almost the same as that of the two lower turves, except that the NTP percentage is rather lower; it is still higher, however, than that for the barrow 4D.

The top 4 in. shows a sequence in which grasses oust woody species, and heath species in turn gain on the grasses. Some weeds of cultivation and cereal appear in the upper spectra, but they may indicate agriculture in the adjacent valley. The topmost sample shows contamination by spoil from a lower level.

Soil characteristics

The buried soil is shallow and intensively bleached, with a well-developed, continuous, thin iron-pan (Plate V, 1). The pollen analyses suggested that the uppermost layers have been removed. In comparing this buried soil with that of Site VII—a neighbouring barrow overlying a peaty gley podzol—it is to be noted that in this case the parent material is much less clayey.

The mineral material associated with the turves is also well leached, but the zone of topsoil from 4 to 8 in. below the present surface is remarkable in that it has quite a marked iron content. While there may have been iron reinforcement from the leached soil above, it is more than coincidence that these four samples, which are distinct in pollen analysis should also be distinct in iron content. Since they are apparently topsoil, it implies that in the vicinity there was soil that was not leached. Taken in conjunction with a lower NTP percentage it may be suggested that it came from a place nearer the forest itself, and therefore more recently cleared. This would accord with the view that the forest itself was on a less leached soil, but that the buried profile developed as the result of clearing.

Site No. VII. BURTON HOWES—BARROW 4D

Place

8 miles due S. of Guisborough, Yorks., N.R.

National grid reference

NZ/608032.

Geology

On a capping of Grey Limestone Series (non-calcareous) of the Lower Oolite.

Topography

Hill-top site overlooking deep valley. Altitude 1,419 ft. O.D.

Present vegetation

Callunetum, with grass on the barrow itself. Considerable moor erosion in the vicinity.

General

This is the largest of a group of round barrows which were being excavated by local archaeologists. The opportunity was taken of obtaining information about the vegetation and soil conditions of the Cleveland watershed in the Bronze Age. The barrow

was primarily a turf mound, but after the insertion of a secondary cremation it was increased in size by a soil covering.

Pollen analysis

The mound was sampled in three series. The lowest ran through two humus bands, the upper one of which was thought to be a cut turf (T2) and the lower the surface humus of the buried soil (T1). Though sampling was continued into the subsoil, the pollen suddenly failed at 3 in. below the lower humus band.

An examination of the pollen distribution shows a sharp change in frequencies and percentages at −1 in., but a gradual change at 0 and +1 in. This indicates that the dark humus band (T1) taken as the buried surface is in fact the upper surface of an inverted turf, superimposed on a soil which is relatively poor in pollen. This is, therefore, probably a truncated soil.

The dark band, T2, stands out clearly by its high frequencies, but the samples both above and below it show big contrasts, probably representing an artificial layering of material.

The second series of samples was taken through a rather ill-defined line which roughly marked the boundary between the primary turf mound and the secondary extension. The series ran through one of the turves (T3). There was some indication of an increase in frequencies at the boundary line, probably confirming that this was in fact a temporarily exposed surface, though since it was not a purely humic layer we are not justified in regarding all the pollen in it as contemporary. Detailed analysis was not, therefore, attempted.

The humic band, T3, however, is more reliable, and its analysis may be compared with that of T1 and T2 from the previous series of samples. Based on the tree pollen count, they give the following spectra:

	Alnus	*Betula*	*Fraxinus*	*Pinus*	*Quercus*	*Tilia*	*Ulmus*	*Corylus*	*NTP*	*ΣTP*
T1 .	48·0	8·0	2·7	4·0	36·0	. .	1·3	93·3	110·7	75
T2 .	56·3	8·9	5·3	1·8	24·1	1·8	1·8	72·3	101·8	112
T3 .	61·1	9·7	1·4	1·4	22·9	0·7	2·1	94·4	137·5	144
Mean	56·5	9·0	3·0	2·1	26·2	0·9	1·8	86·5	119·3	331

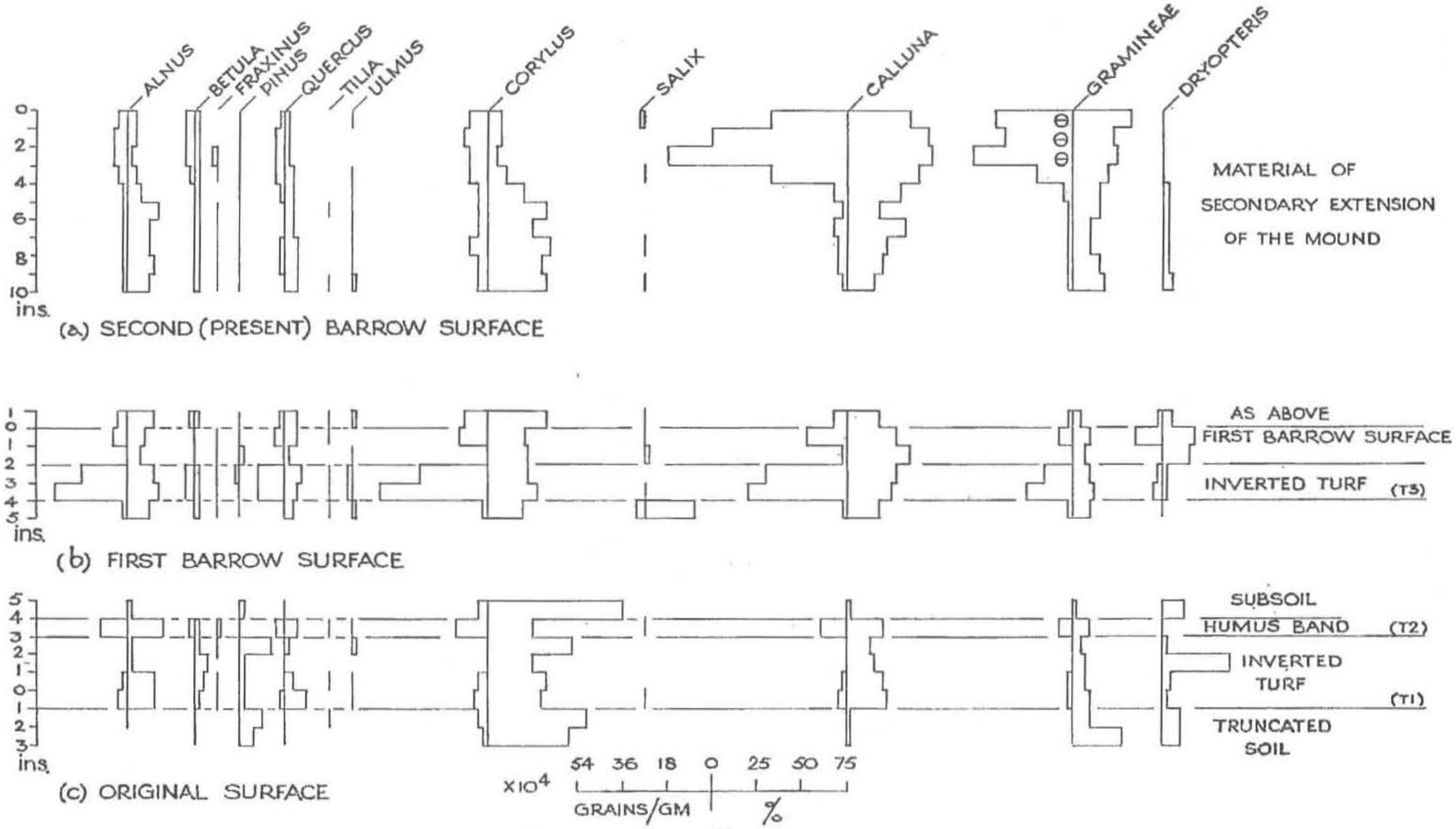
Making due allowance for the fact that the individual tree counts are not statistically adequate, it is obvious that these analyses are all essentially the same. The three have, therefore, been amalgamated to give a mean spectrum. The NTP percentage, 119, indicates conditions of open vegetation, but still within a generally forested area. The vegetation of the site itself was probably grassy heath, but surrounded by mixed forest of *Alnus* and *Quercus*, with *Corylus* important at the margins where it would flower freely.

Comparison with mound 1A (Site VI) shows that these turves have a lower NTP percentage, and are therefore earlier. The forest phase itself is almost identical in the two barrows.

The third series of samples ran downwards from the present surface of the mound. The top four samples probably show the post-barrow pollen, mainly *Calluna* and grasses, but still with some small indication of the influence of woody species. Cereal pollen is seen in the top three samples, but may reflect recent farming activity in the adjacent valley. The samples from 5 to 10 in. are probably unaffected by the post-barrow flora, and the constant spectra apparently reflect the pollen inherent in the mixed material used to extend the mound. Again, since it is not purely humic, one is not strictly justified in making a detailed interpretation, but if a spectrum is produced for this layer, it shows that there is proportionately more grass and *Corylus* as compared with the three turves, but that otherwise the forest species remain in precisely the same proportions.

The overall picture obtained from these data is of a barrow constructed in a forest

BURTON HOWES- BARROW 4D



(9)

clearing, with no indication of cultivation. The barrow was extended following another interment, by which time the extent of the clearing had probably increased, though there was no apparent change in the composition of the background forest at that time. Thereafter, as far as the records go, there seems to have begun the relatively treeless condition of this hill-top, the change coinciding with the disappearance of *Tilia* and the increase in Cyperaceae. The influence of Bronze Age forest clearance, therefore, may not have become really serious until the climatic deterioration.

Soil characteristics

The buried soil (Plate III, 4) is a shallow peaty gley podzol, the eluvial horizon being shown by the A/T profile to be intensively leached. The turves above show low iron content except for the layer T1 and the sample above it. The reason for this is not obvious, but at least it serves to emphasize the sharp break at −1 in.

There is no detectable soil development at the first barrow surface, suggesting that it could only have been exposed for a short period. On the other hand, there is marked removal of iron from the present surface, though in the field this is completely masked by humus-staining. The profile is a shallow peaty gley podzol.

The present moor soil outside the barrow is similar to the buried soil, suggesting that the truncation was only superficial; it must be allowed, however, that there may have been soil movement from the area as a whole, including both sites. This is not to be confused with the modern erosion which is widespread in such places (cf. Plate I, 4).

Site No. VIII. CHICK'S HILL BARROW

Place

3½ miles WSW. of Wareham, Dorset.

National grid reference

SY/869859.

Geology

Eocene: Bagshot Beds.

Topography

Near the crest of a low hill overlooking the Frome valley. Altitude 50 ft. O.D.

Present vegetation

A young oak tree had been standing on one edge of the barrow, which was covered with dense *Pteridium*. The environs were much disturbed, consisting of smallholdings, some abandoned and overgrown.

General

This site is fully described by Ashbee and Dimbleby (2), together with details of soil and pollen analysis.

Pollen analysis

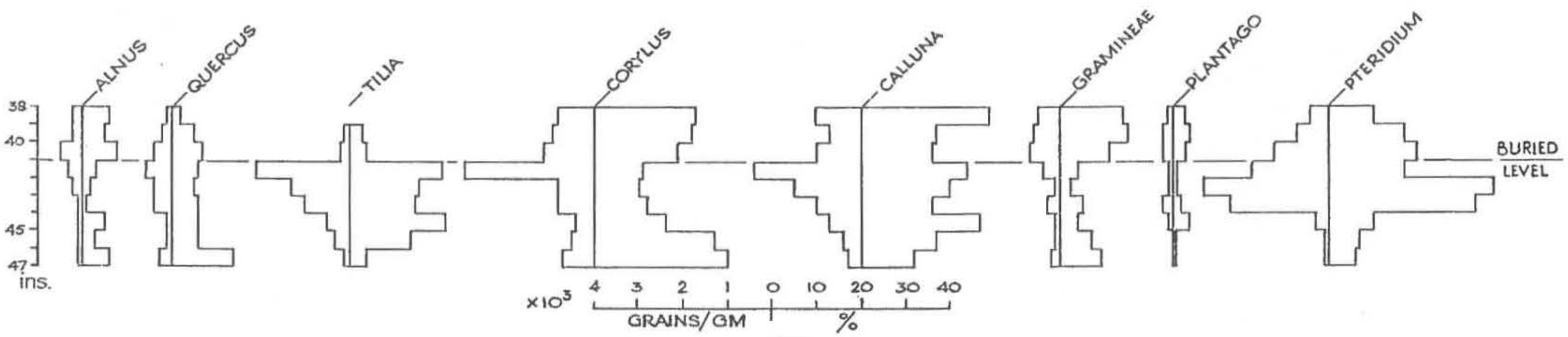
See report referred to above. It is also to be noted, however, that this site provides a good example of a buried level (35).

Soil characteristics

These have been described in the reports already mentioned.

In addition, it may be pointed out here that the depth of the leached layer in the buried podzol is unusually great for a young soil, even allowing that the depth in

CHICKS HILL (BURIED LEVEL ONLY)



(10)

itself is no criterion of age. In this case two points may be mentioned. As the A/T profile indicates, the buried level (35) comes in the middle of the leached layer. If the zone below it represents the topsoil of an earlier soil, it will be predisposed to leaching; consequently the depth of leaching below the Bronze Age surface will be increased by that amount. Secondly, we see here an example of a B horizon developing at or near an interface in the parent material (Plate III, 2). It will be seen from the photograph that the eluvial horizons have developed in gravel which overlies more compact sand. Thus the position of the B horizon was probably predetermined, irrespective of whether the surface of the soil was at its original level or raised by 10 in.

SITE No. IX. COLDHARBOUR

Place

On an unploughed forestry ride 2 miles NW. of Wareham, Dorset.

National grid reference

SY/905899.

Geology

Eocene: Bagshot Beds.

Topography

On steep slope facing SE. Altitude 50 ft. O.D.

Present vegetation

Callunetum, with *Ulex minor* and lichens.

General

The site was about 30 yds. from Dr. Rayner's old experiment on mycorrhiza. Though the forest land had been shallow-ploughed, this site was apparently untouched.

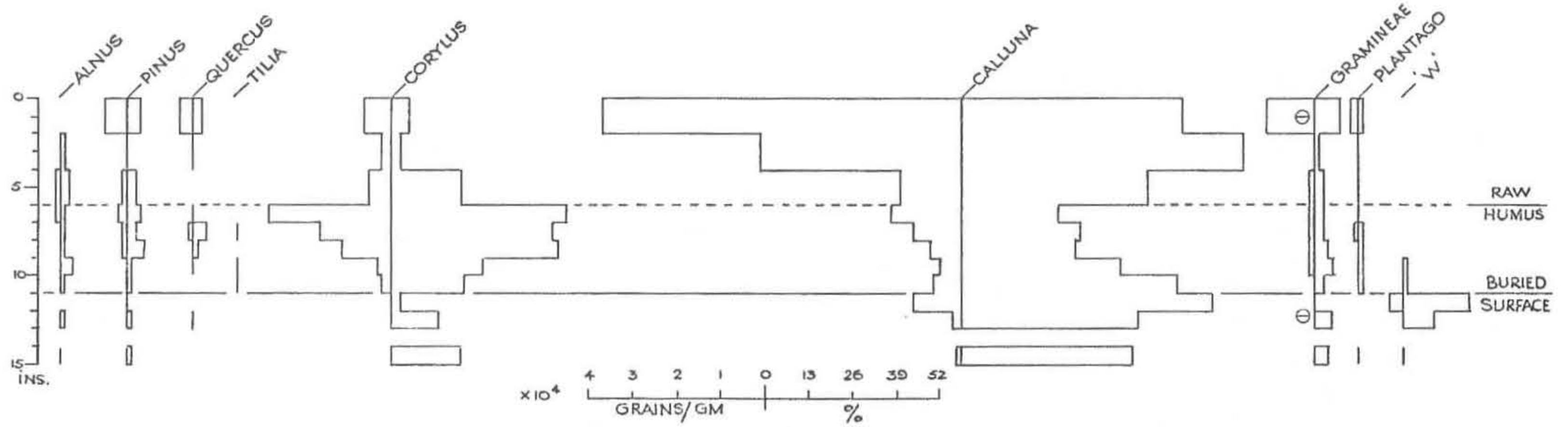
Pollen analysis

Three 2-in. samples were taken through the raw humus layer, which was 6 in. thick. The mineral soil was sampled at 1-in. depths. The upper of the three raw humus samples showed the dominance of *Calluna* but with some small admixture of pollen of grasses, *Pinus*, *Quercus*, and *Corylus*, which could be attributed to near-by influences. The middle zone, however, showed absolute dominance of *Calluna* to the virtual exclusion of all else. The lowest sample, though still dominated by *Calluna*, contained a substantial percentage of *Corylus* pollen, thus providing a link with the high *Corylus* values in the soil beneath.

An unidentified pollen type played an important part in the pollen record in the mineral soil. It has been labelled 'W' and is distinguishable by its enormous size. Drs. H. Godwin and J. Iversen have both examined specimens but are unable to name it. It is of importance in this analysis since it appears in sharply increased amount at 11 in. and is the main pointer to what appears to be a buried level at this depth. The curves of several other species show sudden changes at this depth, but *Calluna* and 'W' are the main species. There is no apparent means of dating this level with any precision.

Above it, *Corylus* increases steadily, while *Calluna* decreases in proportion. *Tilia* is present, and *Quercus* and *Pinus* appear. The grasses and *Plantago* are never high, but they decrease in importance nearer the top of the mineral soil. A general picture is presented of a heathland vegetation, though with *Corylus* present locally, which undergoes progressive change towards woodland, though never to the complete exclusion of

COLDHARBOUR



(11)

Calluna. The period of this would seem to be Sub-boreal, whereas the raw humus above is Sub-atlantic. The high *Corylus* counts in the lower raw humus layer may indicate that there is not a great time interval between the pollen records of the upper part of the mineral soil and the lower layer of raw humus. It must be considered likely, however, that the raw humus itself does not give a continuous record, owing to periodic partial burning.

Soil characteristics

This soil was not fully examined. Samples were collected for pollen analysis, and these samples were used for the preparation of A/T profiles.

The whole of the sampling was within the A horizons, and though a pit was opened to 30-in. depth, no trace of a B horizon was seen. The mineral soil is intensively bleached and it is perhaps significant that even the raw humus contains very little iron.

The upper 10 in. of the A_2 horizon showed parallel humus-stained lines about 1 in. apart, though somewhat irregular in form. These probably account for the variability in the apparent humus-staining in the natural A/T profile. The buried surface at 11 in. cannot be identified from the features of these profiles.

SITE No. X. CROWTHORNE

Place

Near the N. end of Caesar's Camp, 2 miles NE. of Crowthorne, Berks.

National grid reference

SU/863661.

Geology

Eocene: Barton Sand, with surface admixture of Plateau Gravel from hill-wash.

Topography

On gentle N. slope. Altitude 350 ft. O.D.

Present vegetation

Mixed woodland, especially *Betula* and *Castanea*, following heathland.

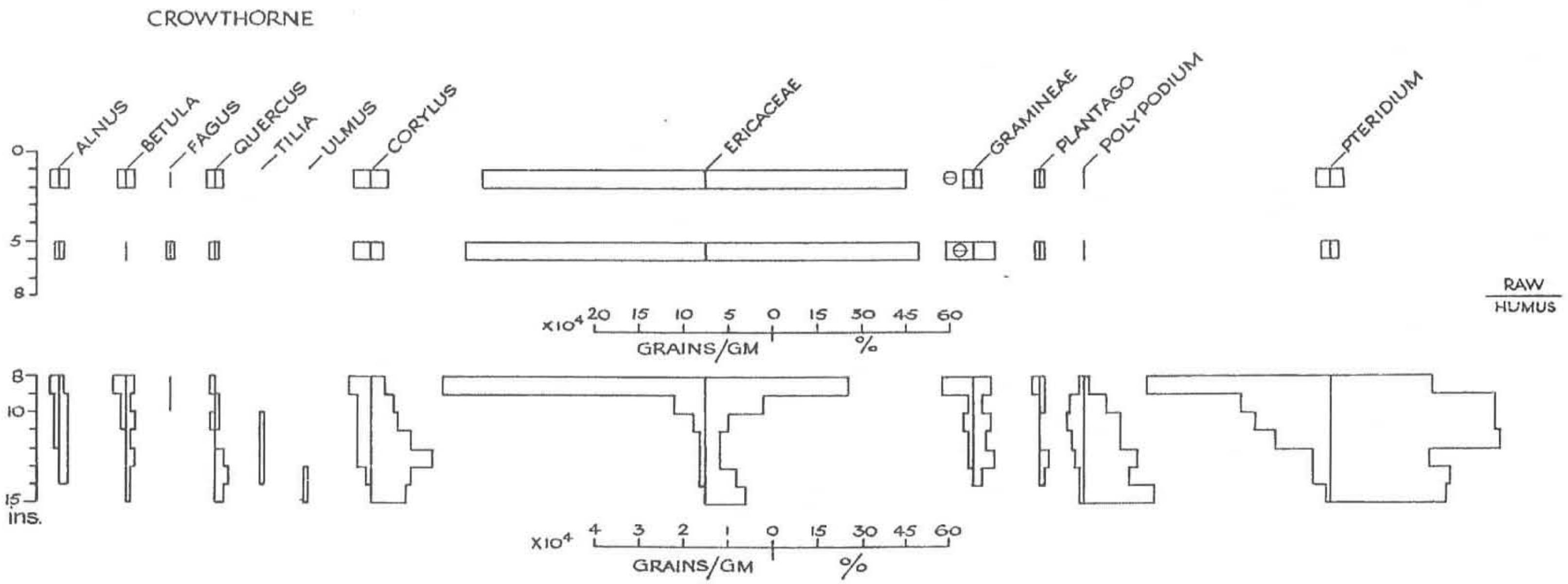
General

Soil section in a bank at side of track leading to Caesar's Camp.

Pollen analysis

The raw humus, being 8 in. thick, was not completely analysed. Samples at 1–2 and 5–6 in. were found to be very similar in pollen spectra, with the Ericaceae clearly predominant and other groups quite subordinate. The upper sample gave some hint of increased woodland growth within the vicinity of the site.

The pollen record in the mineral soil shows throughout a high incidence of *Pteridium*, which is dominant in the earliest phases, associated with *Polypodium*, some Ericaceae and *Corylus*. This suggests a mosaic of *Corylus* thicket and ferny heath. There follows an increase in *Corylus* matched by a decrease in Ericaceae; at the same time Gramineae and *Plantago* appear. *Tilia* is also present at this stage. Gradually, however, the *Corylus* decreases and *Pteridium* becomes even more predominant, though in the uppermost layers the rapid spread of Ericaceae brings it to co-dominance, at any rate as far as the counts can tell us.


CROWTHORNE
ALNUS
BETULA
FAGUS
QUERCUS
TILIA
ULMUS
CORYLUS
ERICACEAE
GRAMINEAE
PLANTAGO
POLYPODIUM
PTERIDIUM
0
5
8
10
15
ins.
RAW HUMUS
X10⁴ 20 15 10 5 0 15 30 45 60
GRAINS/GM
%
X10⁴ 4 3 2 1 0 15 30 45 60
GRAINS/GM
%

(12)

Soil characteristics

This soil is a well-developed humus–iron podzol, closely resembling New Forest heath soils on the same geological formation.

SITE No. XI. DECOY HEATH

Place

Decoy Heath. 3 miles N. of Wareham, Dorset.

National grid reference

SY/917920.

Geology

Eocene: Bagshot Beds.

Topography

On level ground at the top of a low, south-facing ridge. Altitude 50 ft. O.D.

Present vegetation

Calluna heath.

General

The soil material is a coarse sand, the characteristic 'sugar sand' of this area.

Pollen analysis

There is a probable buried level at 8 in., with *Myrica* suddenly becoming predominant (cf. Pondhead) and both it and *Corylus* showing a sharp increase in frequency. The counts obtained below this level were inadequate for a reliable estimate of percentages, with the frequencies and number of species both falling rapidly.

Above this 8-in. level Ericaceae and *Corylus* are jointly in the majority, but *Corylus* increases whereas the Ericaceae maintain a high but static percentage. Finally, however, Ericaceae, accompanied by grasses and *Plantago* at lower values, become predominant while *Corylus* shows a decrease. There is no means of establishing the date of these changes with certainty, but the lack of *Tilia* as a consistent component may indicate the latter part of the Sub-boreal and into the Sub-atlantic. No dating of the buried surface can be attempted from these data.

Soil characteristics

This is an intensively developed humus podzol (Plate II, 3), closely comparable with similar soils developed on Barton Sand (e.g. Burley Heath). The A/T profile gives no indication of the buried surface which occurs within the bleached A_2 horizon.

SITE No. XII. GOODLAND

Place

3 miles due E. of Ballycastle, Co. Antrim, Northern Ireland.

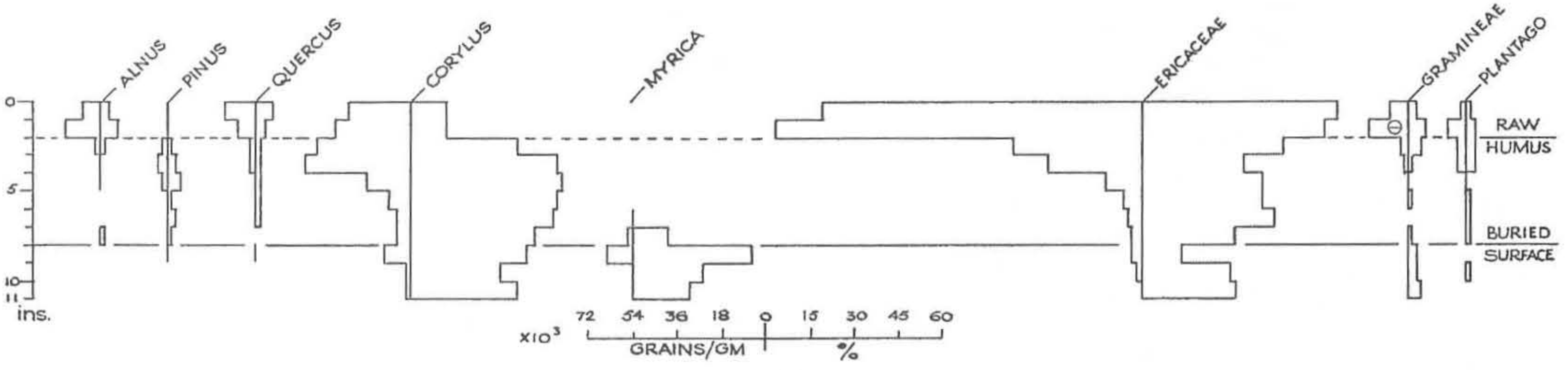
Geographical co-ordinates

55° 11′ 58″ N.; 6° 6′ 27″ W.

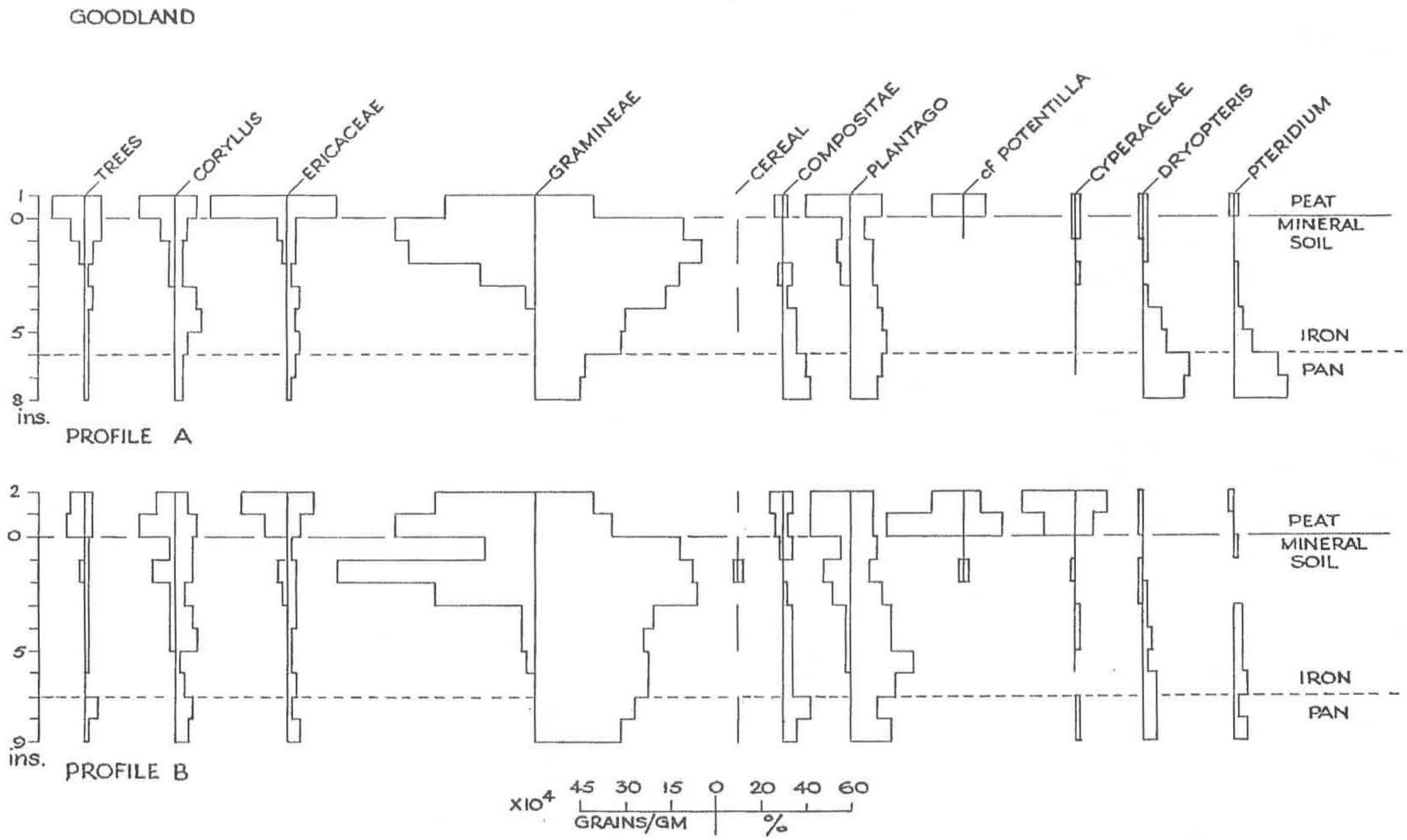
Geology

Boulder Clay overlying chalk.

DECOY HEATH



(13)


GOODLAND
TREES
CORYLUS
ERICACEAE
GRAMINEAE
CEREAL
COMPOSITAE
PLANTAGO
cf POTENTILLA
CYPERACEAE
DRYOPTERIS
PTERIDIUM
PEAT
MINERAL SOIL
IRON PAN
ins.
PROFILE A
PROFILE B
X10[4] 45 30 15 0 20 40 60
GRAINS/GM
%

Topography

In a valley between chalk down on one side and bog-covered boulder clay on the other. Altitude 750 ft. O.D.

Present vegetation

The site lies beneath 4–5 ft. of blanket-bog peat.

General

The investigation of this Neolithic site was made at the instigation of H. J. Case, Ashmolean Museum, Oxford, who was in charge of the archaeological work.

Pollen analysis

See report in Case (12).

It is apparent that the whole of the pollen record falls in a period later than Neolithic forest clearance but earlier than Sub-atlantic peat formation. It presents a picture of grassland with associated weeds, under which conditions the soil changes had occurred.

Soil characteristics

See Proudfoot (85).

The thin iron-pan soil had developed since Neolithic clearance and before bog formation. It had formed under a grassland vegetation.

Site No. XIII. HIGH ROCKS

Place

2 miles WSW. of Tunbridge Wells, Kent.

National grid reference

TQ/561384.

Geology

An outcrop of the Tunbridge Wells Sand of the Hastings Beds of the Wealden Series.

Topography

The High Rocks consist of a series of precipitous cliffs, up to 50 ft. high, where the Sand outcrops. These are dissected by ravines, and each cliff is somewhat undercut. The Mesolithic sites occur beneath the overhang and have become covered by aggrading sand.

Present vegetation

Deciduous woodland, much disturbed, including *Quercus*, *Betula*, *Acer pseudoplatanus*, *Taxus*, *Corylus* (on the overlying clay), and abundant ferns (*Pteridium* and *Dryopteris filix-mas*).

General

Owing to the nature of the site it is not susceptible to the normal treatment. It has been excavated by J. H. Money (his Site F), who has supplied samples from various levels for pollen analysis. He was not able to locate a buried occupation level on an undisturbed soil.

Pollen analysis

Detailed analyses will be found in Money's report when it is published. In summary, it may be said that the vegetation of the Mesolithic/Neolithic period in which the

site falls was deciduous forest with *Quercus*, *Betula*, and *Fagus* as the main trees. The consistent occurrence of *Fagus* throughout the history of this site is the only case known to me in which *Fagus* can be shown to be of ancient standing on an acid soil.

The Ericaceae were poorly represented, as also were the grasses and weeds of cultivation. The top six samples were of topsoil material.

Soil characteristics

Any statements about the soil can only be made on individual samples, since no undisturbed profile was revealed. Bearing in mind, however, that the soil material was topsoil that had aggraded during the occupations identified by the artifacts, it seems that when the Neolithic period came in this site had a bleached topsoil, and, as has been shown above, this topsoil was associated with a deciduous forest flora. The pH today is between 3·1 and 3·9 at all levels, so it seems likely that here, as at Keston, is a base-poor material which podzolized under deciduous forest.

The known properties of *Fagus* as a soil-deteriorating species when growing on acid soils may not be unconnected with the observed state of this soil.

Site No. XIV. KESTON CAMP

Place

Caesar's Camp, Holwood Park, Keston, 4 miles SSE. of Bromley, Kent.

National grid reference

TQ/421637.

Geology

Eocene: Blackheath Pebble Beds.

Topography

On a plateau gently dipping to the N. Altitude 500 ft. O.D.

Present vegetation

Very mixed. The earthworks themselves are largely covered with *Pteridium*, but much woodland occurs with both native and exotic species, much of it dating back to nineteenth-century planting.

General

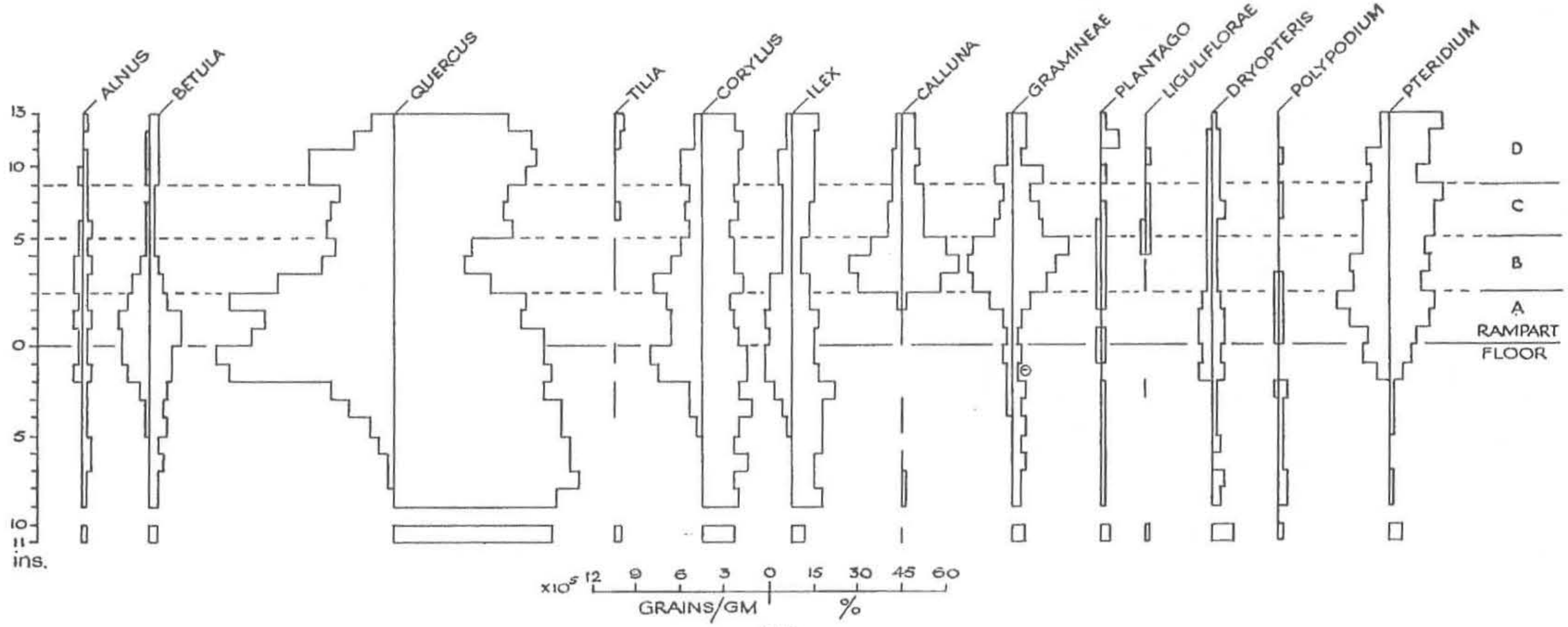
This Iron Age camp has been levelled over most of its circumference. The ramparts and ditches are, however, intact at the SW. corner.

Pollen analysis

The old floor on which the rampart was built stands out clearly from the pollen analysis. The vegetation at the time of construction was a forest of *Quercus* with *Corylus*, *Betula*, and *Ilex* as subordinate species. The very low values for pollen of light-demanding herbs proves that the canopy was close and complete, though there is evidence of a limited increase of *Pteridium* prior to burial, which might indicate some disturbance in the forest. The pollen record is surprisingly consistent with depth and though no time scale can be put on it, it is clear that the forest had persisted for a long time. The association of species suggests that the forest was ecologically stable, and there is no indication that on this site it was secondary. The chronological limitations of the pollen record, however, do not allow this to be taken as proof of the primary nature of the forest.

The sampling was continued upwards into the rampart and this material is seen to be heterogeneous, being made up of layers. Layer A corresponds in pollen spectrum

KESTON CAMP (BURIED SOIL)



to the surface layers of the buried soil and presumably came from the initial excavations of the ditch. Layer B has a higher proportion of *Calluna* and grass pollen and cannot have come from the immediate environment, and the same appears to be true of layer C, which, though having lower values of *Calluna* and grass pollen than B, greatly exceeds the buried soil in this respect. Finally, layer D is characterized by even less of these two types, but more *Quercus* pollen.

The absolute frequencies of all these layers are high and, from comparison with the buried soil, it would seem reasonable to assume that all the superimposed material was topsoil, coming from the uppermost 5 in. only. It must be borne in mind, however, that the upper part of the rampart has not been analysed, so no statement is possible from the pollen analyses as to its origin.

Soil characteristics

The buried soil has the appearance of a well-developed humus–iron podzol with an intensively leached A horizon varying from 6 in. to 2 ft. in depth (Plate VII, 2). The B horizon is also strongly developed, with accumulation of both humic and iron materials, but not indurated.

Site No. XV. KESTON COMMON

Place

On common land $\frac{3}{4}$ mile S. of Keston, Kent.

National grid reference

TQ/418639.

Geology

Eocene: Blackheath Pebble Beds.

Topography

On edge of old gravel workings. Undisturbed ground slopes gently to the N. Altitude 450 ft. O.D.

Present vegetation

Mosaic of *Calluna*, young stands of *Betula*, and scattered *Pinus*. The site sampled was immediately beneath a medium-sized pine tree.

General

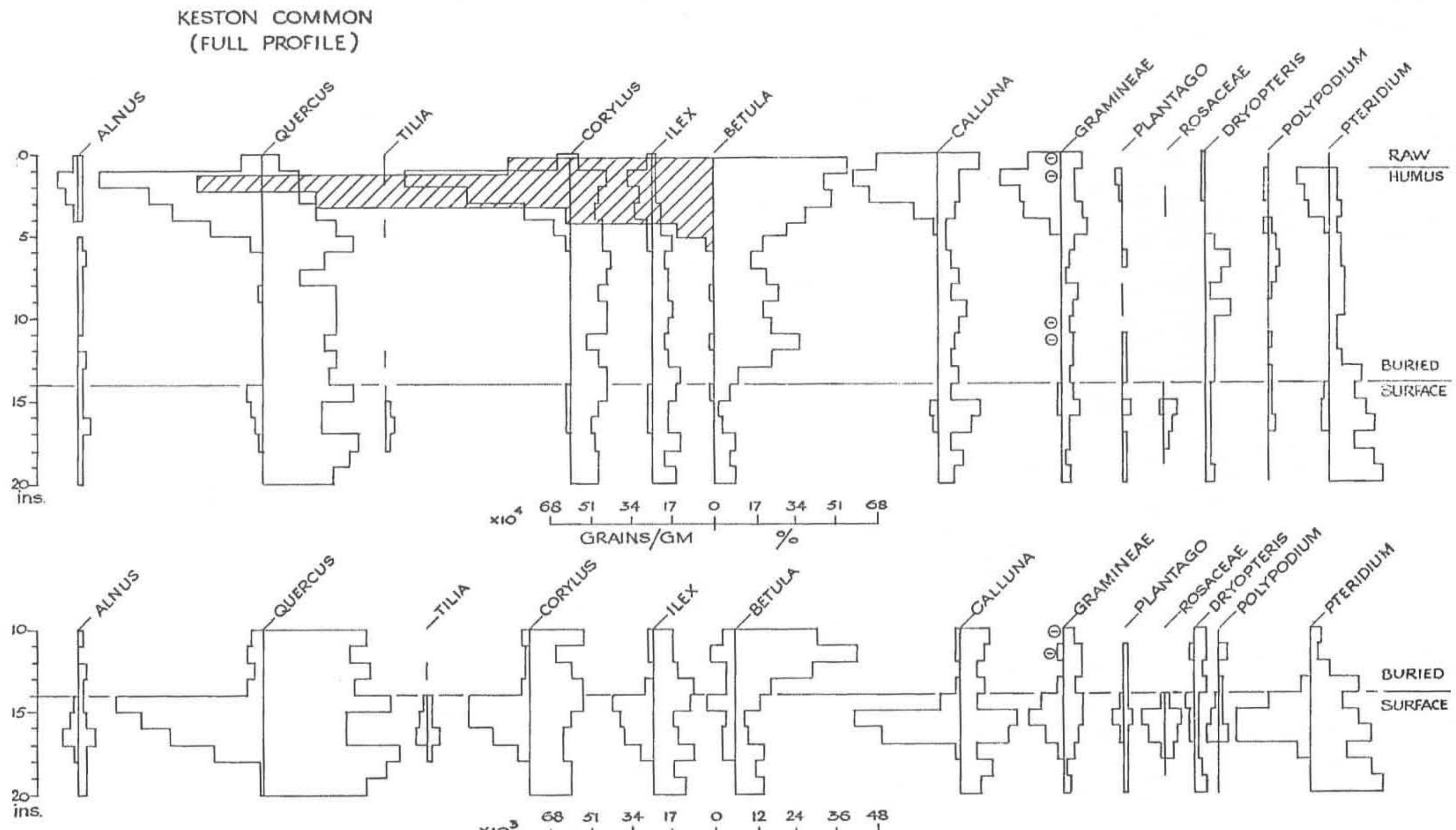
This site was chosen to serve as a comparison with the soil beneath the rampart of Caesar's Camp, in Holwood Park, Keston (Site XIV).

Pollen analysis

The pollen diagram falls into two clear sections. There is an obvious buried level at 14 in., separating the two.

The older section shows predominantly a woodland spectrum, *Quercus*, *Corylus*, and *Pteridium*, with lesser quantities of *Ilex* and *Betula*. Initially the light-demanding grasses and *Calluna* are quite subordinate. Then comes an increase in *Calluna*, Rosaceae, *Pteridium*, and to a lesser extent Gramineae and *Plantago*. The above-mentioned trees all fall back in proportion, but there is a brief increase of *Alnus* and *Tilia*. (This could be due to an increase in distant pollen resulting from an opening of the canopy.) This phase, however, is short-lived, and the oak forest returns to its former dominance before the site is overwhelmed.

The pollen spectra immediately above the buried surface show certain differences from those below, in percentages as well as frequencies. In particular, *Betula* becomes



KESTON COMMON
(FULL PROFILE)
ALNUS
QUERCUS
TILIA
CORYLUS
ILEX
BETULA
CALLUNA
GRAMINEAE
PLANTAGO
ROSACEAE
DRYOPTERIS
POLYPODIUM
PTERIDIUM
RAW
HUMUS
BURIED
SURFACE
0
5
10
15
20
ins.
x10⁴ 68 51 34 17 0 17 34 51 68
GRAINS/GM %
ALNUS
QUERCUS
TILIA
CORYLUS
ILEX
BETULA
CALLUNA
GRAMINEAE
PLANTAGO
ROSACEAE
DRYOPTERIS
POLYPODIUM
PTERIDIUM
BURIED
SURFACE
10
15
20
ins.
x10³ 68 51 34 17 0 12 24 36 48
GRAINS/GM %

much more important, but *Quercus*, *Corylus*, and *Ilex* remain relatively about the same. *Pteridium* wanes, and none of the field layer species increases. Cereal pollen was recorded at 9–11 in. but the small grass and weed counts do not suggest that cereals were actually grown on this site.

It is of particular importance to note that at no time is *Calluna* present in even moderate percentages. This site has never been under heathland; the highest *Calluna* percentage is reached at the present surface, and even this is low. A fifteenth-century map describes this area as 'Keston Hethe', but it is clear that this was not heath as understood today.

The modern (but not dated) pollen record shows a break in the hold of the forest. *Quercus* and *Ilex* fall away, and there is an enormous increase in *Betula*, presumably a reflection of burning. At the same time there is some increase in grasses and *Calluna*, indicating more open conditions. Cereal pollen is also found in the upper layers, but again the associated pollen types do not provide evidence of cultivation.

The time scale of this record is highly problematical. The surface was buried while *Tilia* was still in the natural forest, so one would expect the burial to have taken place before the construction of the near-by Iron Age Camp (in the buried soil of which *Tilia* was much less predominant). Otherwise, the forest picture is in general very similar to that of the buried soil at the camp, though the dominance of *Quercus* is not quite so complete, and it persists, as far as one can judge, into historical and probably medieval times.

Soil characteristics

This soil is a podzol with a massive B horizon, indurated over a considerable depth (Plate II, 4). This induration of the B horizon is in marked contrast to the uncemented B horizon of the soil buried under the rampart.

The A/T ignition profile, in conjunction with the pollen analyses, suggests that this soil is a composite of two superimposed podzols. The modern podzol is clear, but below the 14-in. level the material is less iron-rich; it would be reasonable to assume that the irregularity of the iron colour in this layer is a secondary effect. From 22 to 27 in. there is some indication of a reinforcement of both the humus and iron colours. This can be seen quite distinctly in the soil section.

If this interpretation is correct, and it is also accepted that the 14-in. surface was covered before the Iron Age, then comparison with the soil under the rampart is not strictly possible, since the soil buried in this profile will be younger than the one buried at the camp, and we can only guess the interval.

What is apparent, however, is that in both buried soils considerable podzolization had gone on under a deciduous forest cover. The intensity of leaching in the two cases is difficult to compare; certainly there is more iron in the younger soil, but how much of this is due to podzolization at the present surface it is impossible to say. On this evidence the iron accumulations in the two B horizons do not appear to be dissimilar.

The modern podzol is intensively developed, and it must be accepted that heath vegetation can only have influenced this in very recent times. The enormous amount of *Betula* pollen indicates the dominance of a species generally regarded as soil-improving; clearly other factors have been overriding. It seems reasonable to assume that, since podzolization took place under oak forest in the buried soils, it has also been taking place—again largely under oak—from the time that this material was laid down in its present position, probably more than 2,500 years ago.

Site No. XVI. KESTON COPSE

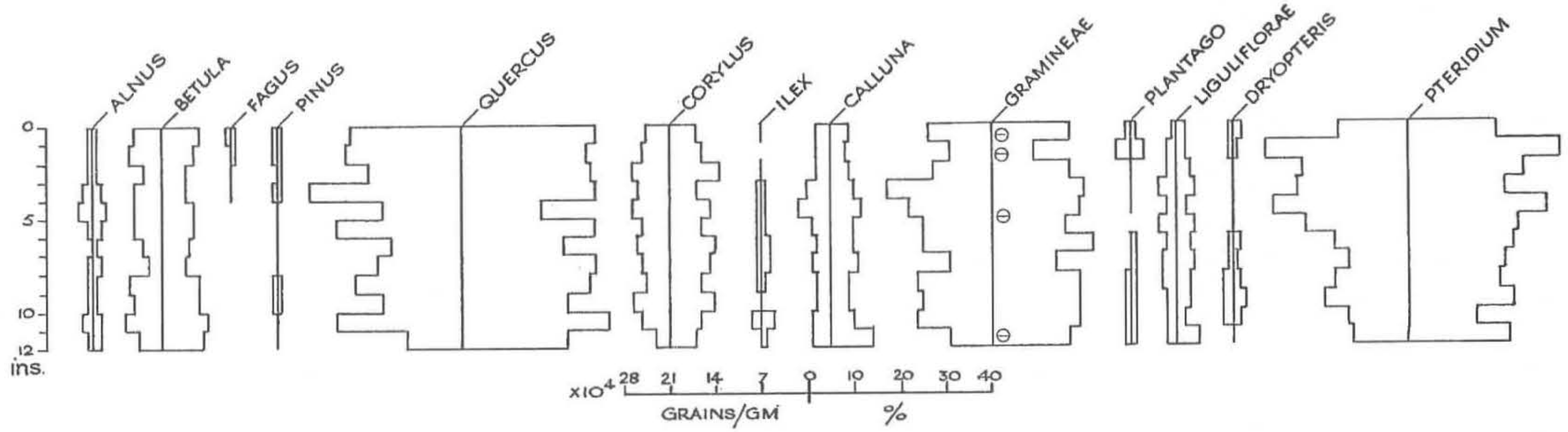
Place

Caesar's Camp, Holwood Park, Keston, 4 miles SSE. of Bromley, Kent.

National grid reference

TQ/421637.

KESTON COPSE



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F

Geology

Eocene: Blackheath Pebble Beds.

Topography

On a plateau gently dipping to the N. Altitude 500 ft. O.D.

Present vegetation

Sub-spontaneous woodland of *Acer pseudoplatanus* and other occasional species.

General

This site was only about 20 yds. NE. of Site XIV. It was selected to test the hypothesis that the topsoil used in the later construction of the inner rampart had merely been scraped up from the adjacent land surface, a hypothesis which was not confirmed.

Pollen analysis

The pollen distribution through the 12 in. sampled is almost uniform both in quantity and proportions of the main species. *Quercus* and *Pteridium* are the main species, with the grasses very close behind. *Betula* and *Corylus* are consistently present in moderate proportion, but *Calluna*—for this species—is not abundant. The Liguliflorae and, to a lesser extent, *Plantago*, represent cultivation weeds, and cereal pollen occurs sporadically throughout.

The state of the pollen was not good; much of it was corroded and damaged. This would accord with the belief that this is a biologically active soil in which breakdown is becoming vigorous. Moreover, the uniformity of the spectra at all depths suggests considerable mixing of the soil. This being so, it is impossible to say whether the different pollen groups are contemporary or not.

Soil characteristics

It is apparent from the soil profile that this soil has been strongly podzolized, as there is a well-developed B horizon at about 15 in. Above this, however, there is no apparent bleached layer. The eluvial layers are indistinguishable, being throughout black and humus-rich, with very abundant rooting; good structure is developed in the top few inches.

It must be assumed, therefore, that this is a regenerated podzol. The A/T ignition profile covers only the twelve samples used for pollen analysis, but it indicates that the soil, especially in the uppermost layers, is not devoid of iron. It is difficult to be sure that it has ever been completely bleached, but it must be remembered that other regenerating podzols (Pondhead; Suffield Moor—Birch) have been shown to have a redevelopment of the iron colour in the new mull layer.

The depth of the eluvial layer, in comparison with the buried soil under the rampart, leaves little doubt that this soil has not been truncated as a source of material for the construction of the rampart.

There is no evidence from old maps that this particular area has been cultivated, as there is for the eastern half of the camp enclosure, but the possibility cannot be excluded. An ornamental plantation was established near this spot in the early nineteenth century.

SITE NO. XVII. LUN RIGG

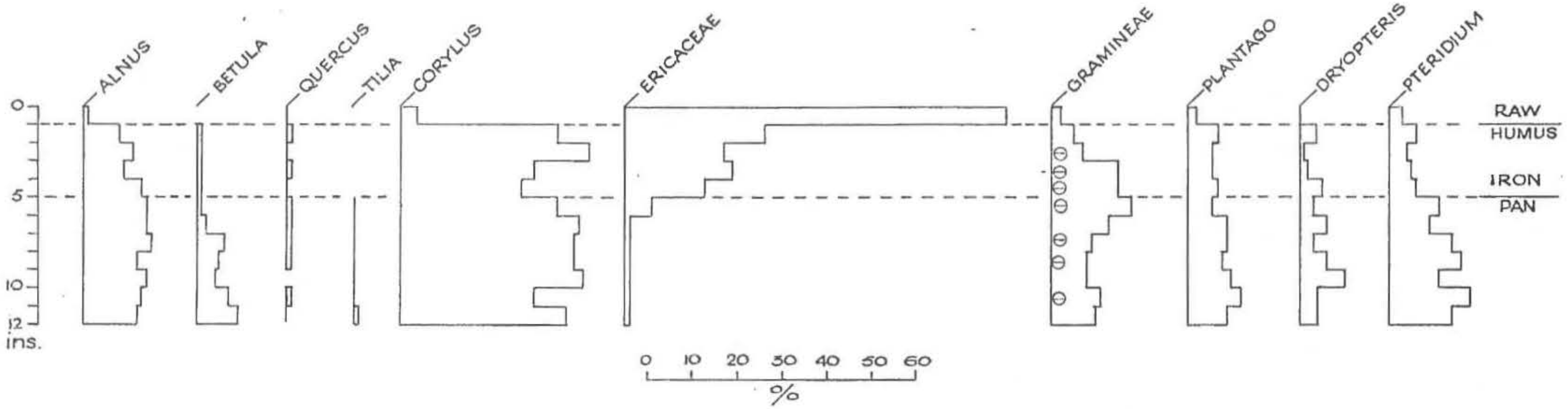
Place

On Wykeham High Moor, 8½ miles WNW. of Scarborough, Yorks., N.R.

National grid reference

SE/920953.

LUN RIGG



ALNUS
BETULA
QUERCUS
TILIA
CORYLUS
ERICACEAE
GRAMINEAE
PLANTAGO
DRYOPTERIS
PTERIDIUM
RAW
HUMUS
IRON
PAN
0
5
10
12
ins.
0 10 20 30 40 50 60
%

(18)

Geology

Jurassic: Kellaways Rock of the Middle Oolite.

Topography

Flat ridge-top site. Recently deep-ploughed. Altitude 630 ft. O.D.

Present vegetation

Calluna heath, but planted up with pine and spruce after ploughing.

General

Attention was focused on this site by Messrs. W. H. Lamplough and J. R. Lidster, who discovered Iron Age pottery and a hearth after the area had been ploughed. There was no evidence of earthworks of any sort, and the sherds of pottery occurred mainly in the iron-pan, with which they were cemented. Charcoal of *Quercus* and *Corylus* was identified from the hearth. This profile was taken from a point where the original soil had not been disturbed by the plough.

Pollen analysis

This analysis was carried out before it had become the practice to work on standard quantities of material. Consequently only percentages are available, though the number of slides scanned is a rough guide to frequency in this case. There is not a drastic fall with depth.

Apart from the raw humus, in which the Ericaceae are absolutely dominant, the pollen throughout shows a high proportion of *Corylus*, which is the most abundant species at all levels of the mineral soil. The Ericaceae fall away rapidly with depth, and obviously post-date the rest of the pollen record.

There is some increase of woody species below the iron-pan; apart from *Corylus*, *Alnus* is well represented, and *Betula* is here present to a greater degree than higher up. *Tilia* is present in small quantity below the pan but not above it. It is noticed that *Quercus* attains no importance at any level. *Pteridium* is better represented below the pan than above it, and especially significant is the relatively high proportion of *Plantago* and the consistent occurrence of cereal pollen though the grasses themselves are not over-abundant.

The pan does not form a very marked barrier and it is apparent that it formed at a late stage relative to much of the pollen. Above it the pollen record is marked by the increase in the Ericaceae, while the grasses, *Pteridium*, and, to a lesser extent, *Alnus*, fall away. Since this is only a percentage diagram, however, it cannot be assumed that these changes are coeval; it is possible that the bulk of the ericoid pollen is younger than any of the other pollen types in the mineral soil. It must also be borne in mind that there is a marked discontinuity at the junction between mineral soil and raw humus, and the period of time represented by this is quite unknown.

Soil characteristics

The soil is a typical shallow heath podzol with an indurated thin iron-pan. The A_2 horizon, though humus-stained, is intensely leached of iron. This must be seen, however, as a relatively late process. The pottery was buried by about 4 in. of mineral soil, possibly by surface aggradation, though a more likely explanation would seem to be earthworm activity; the flora revealed by pollen analysis points to a soil type which, on the face of it, should have supported an earthworm population. But, as at Goodland, it is probably necessary to assume that the pollen record did not begin until the earthworm activity had almost ceased, because the soil movement by worms would destroy a pre-existing pollen stratification (cf. Keston Copse). Moreover, under conditions of acidity favourable for earthworm activity the preservation of pollen would be poor. Thus we see the pollen spectrum as representing the flora after degradation of the site was under way, and this degradation seems to have taken place under hardwood

scrub vegetation, with heath becoming progressively more widespread. In many ways this soil is very similar to that at Goodland, even to the extent of having a suggestion of iron accumulation below the indurated pan (7–10 in.). The formation of the shallow pan can therefore be seen as a subsequent development, and as at Goodland it has formed at a zone where sherds of pottery have been buried, apparently by earthworm activity.

Site No. XVIII. LYNDHURST—THE RIDGE

Place

¾ mile ESE. of Lyndhurst, Hants.

National grid reference

SU/312079.

Geology

Eocene: Barton Sand with superficial admixture of Plateau Gravel.

Topography

Ridge-top site, the land falling gently to the NE. and more steeply to the SW. Altitude 150 ft. O.D.

Present vegetation

Much *Ulex europaeus* on the earthwork, otherwise *Calluna* heath more or less mixed with grass.

General

This is a section through an earthwork constructed to enclose Lyndhurst Manor and Park, assigned in 1299 as part of the dower of Margaret on her marriage to Edward I. The enclosing ditch and palisades were ruinous by 1428 (Sumner, 107). The section is through the bank and into the undisturbed medieval soil beneath.

Pollen analysis

Two series of samples were analysed: one from the present surface downwards, and the other through the buried surface.

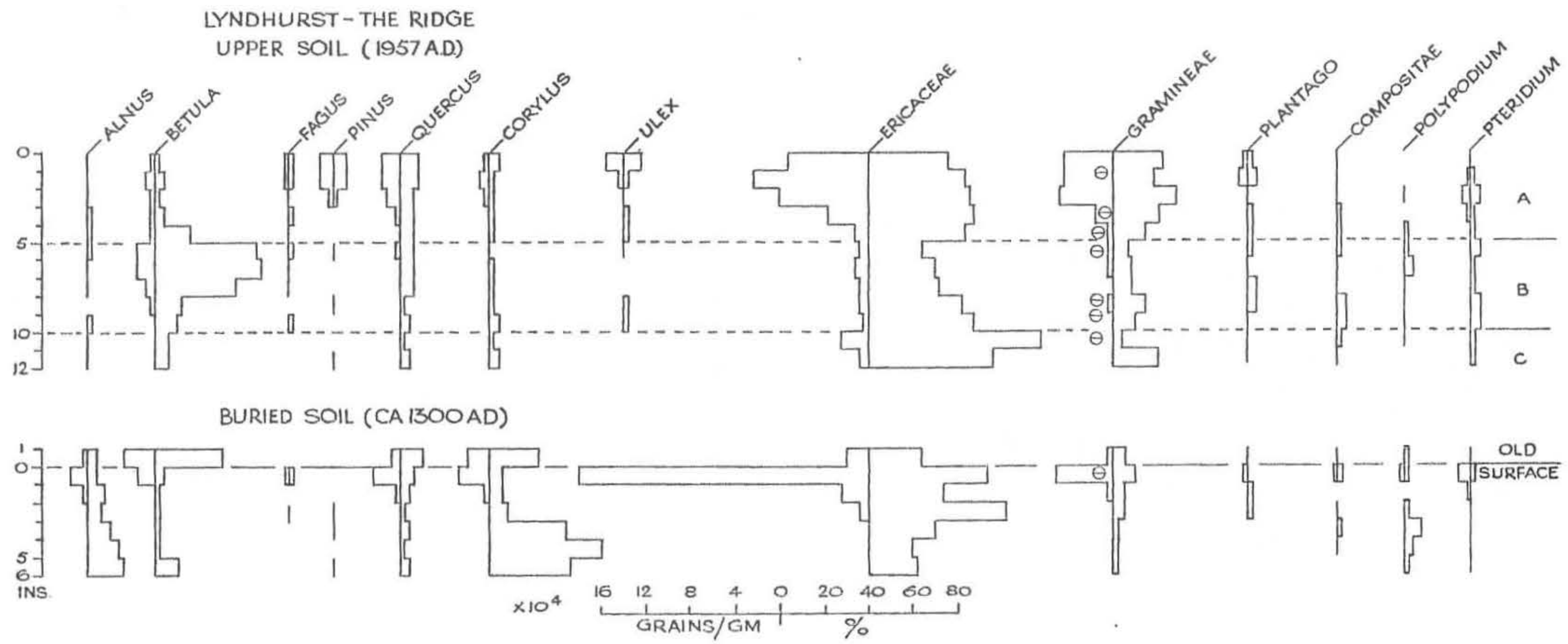
The upper profile is clearly heterogeneous; the soil material falls into three distinct layers, separated from each other by abrupt changes in frequency and percentage. The top 5 in. (A) shows the pollen record of recent times, with Ericaceae and grasses forming the bulk of the pollen; of the tree species, *Quercus* is the best represented, with *Pinus* increasing in the uppermost samples. The present dominance of *Ulex* on the earthwork is also reflected in the top sample.

The next zone (B) has generally lower frequencies, except for *Betula*, which replaces Ericaceae as the most abundant pollen in the 5–8-in. region, though the latter are dominant from 8 to 10 in.

At 10 in. there is a sudden increase in both frequency and percentage of Ericaceae, obviously another surface. These zones may be attributable to phases of construction of the bank, or they may be the result of repairs to the structures such as are mentioned in the historical records (Sumner, 107).

The buried soil shows an enormous excess of Ericaceae pollen at the visible surface, but the frequency rapidly falls with depth, the percentage doing so less rapidly. At 3–4 in. below this surface *Corylus* takes over as the most abundant species, with *Alnus* jointly increasing to a lesser extent. The pollen record peters out at 6 in.

This profile is poor in grasses compared with the recent one; cereal pollen is only found in the buried surface itself, whereas it is present practically throughout the


LYNDHURST - THE RIDGE
UPPER SOIL (1957 A.D.)
ALNUS
BETULA
FAGUS
PINUS
QUERCUS
CORYLUS
ULEX
ERICACEAE
GRAMINEAE
PLANTAGO
COMPOSITAE
POLYPODIUM
PTERIDIUM
A
B
C
BURIED SOIL (CA 1300 AD)
OLD
SURFACE
INS.
x10^4
16 12 8 4 0 20 40 60 80
GRAINS/GM
%

upper profile. In neither case, however, does it seem likely that cultivation had taken place near the site—at any rate during or since medieval times.

It is surprising that the soil sample immediately overlying the buried surface should show a spectrum contrasting so markedly with the soil beneath, since it seems likely that this material was topsoil from the ditch. There may have persisted small thickets of *Betula* and *Corylus*, which would have been a source of topsoil with such a spectrum.

Soil characteristics

The A/T ignition profile bears out the deduction from the pollen analyses that the upper profile is heterogeneous; the three zones correspond except that there is a 1-in. discrepancy in the boundary between A and B. This may be due to the true boundary falling between 4 and 5 in.; the increase in the percentage of *Betula* pollen in this sample may reflect the same thing.

Zone B is characterized by a much more pronounced iron colour after ignition than the other two zones. This may have been added to by iron movement from zone A (especially affecting the 4–5-in. sample), but in fact the degree of leaching of the uppermost zone is surprisingly slight considering that the soil has been under heath vegetation for several hundred years. Judging by the amount of iron residual in zone A, the material was of subsoil origin. This is also borne out by the pollen analyses, which show no concentration of pollen of any but species which could be assumed to be recent. In particular *Corylus* is very poorly represented.

The whole profile through the bank shows crudely an inverted podzol profile on top of the old surface, strongly suggesting that the material was thrown out of the ditch in layers from successively greater depths (Plate VIII, 3). The buried soil itself was intensely leached and showed a massive humus–iron podzol profile closely resembling that of the surrounding heath (Plate VIII, 1). It is apparent that this heath profile has not changed visibly in the past 650 years.

SITE No. XIX. LYNDHURST—WHITE MOOR

Place

On the S. edge of White Moor, 1 mile ESE. of Lyndhurst, Hants.

National grid reference

SU/314077.

Geology

Eocene: Barton Sand.

Topography

On moderate slope facing SSW. Altitude 120 ft. O.D.

Present vegetation

Calluna heath.

General

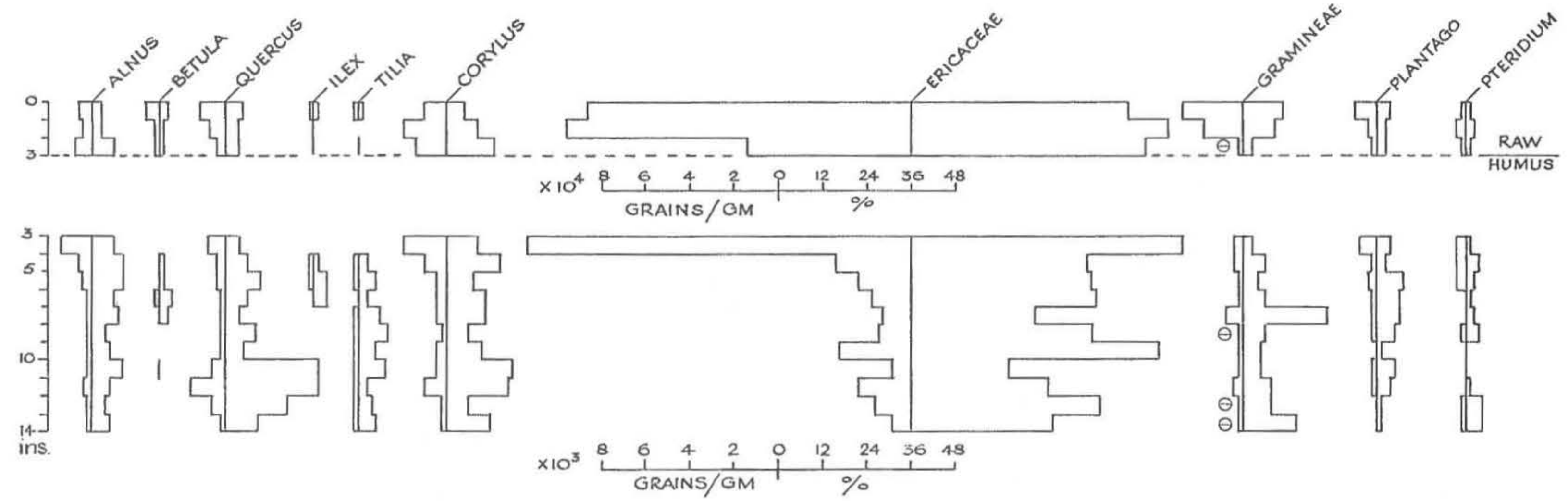
To serve as a comparison with Pondhead (Site XXII) and with The Ridge (Site XVIII).

Pollen analysis

This proved to be an example of a heathland soil which is very poor in pollen. Only by excessive labour was it possible to obtain counts of over 200 grains.

The pollen record here is obscure, and one is left with a suspicion that the distribution is not determined only by downwash through the soil. Whether hill wash, soil

LYNDHURST-WHITE MOOR



(20)

stratification, or root channels have played some part cannot be said, but the results cannot be interpreted with confidence.

Ericaceae are dominant at all levels, and cereal pollen is found even in the lowermost samples, suggesting that the whole pollen record is relatively recent. This is somewhat belied by the consistent presence of *Tilia* in moderate proportions, yet the rather low percentages of *Corylus* and the steady occurrence of *Plantago* again suggest recency. Indeed, this may be a case where *Tilia* is over-represented through differential breakdown, for it must be borne in mind that the total frequencies are extremely low.

Soil characteristics

The photograph (Plate VIII, 2) shows more readily than words the magnificent development of the humus–iron podzol The A_1 horizon is unusually deep, about 7 in., and the underlying A_2 is intensively leached. Horizontal dark-coloured striations through the bleached layer reflect what is assumed to be the natural stratification of the sand. The B horizon is extremely compacted, though without an indurated iron-pan. Humus deposition occurs at three main levels, but subsidiary bands are also picked out. The iron deposition is diffuse rather than concentrated.

A feature of the B horizon is the peculiar lobing of the upper surface, seen so clearly in the photograph.

The A/T profiles do not extend through the whole of the B horizon, but they emphasize the intense bleaching of the eluvial zone.

Plate VIII, 1, shows another variant of the profile on this moor, and the two together compare interestingly with the buried soil under The Ridge, which itself shows great variation over a short distance (Plate VIII, 3).

SITE No. XX. MATLEY WOOD

Place

2 miles E. of Lyndhurst, Hants.

National grid reference

SU/332076.

Geology

Pleistocene: Plateau Gravel overlying Barton Sand (Eocene).

Topography

Gentle slope to the N. Altitude 110 ft. O.D.

Present vegetation

Oakwood. Largest trees about 250 years old.

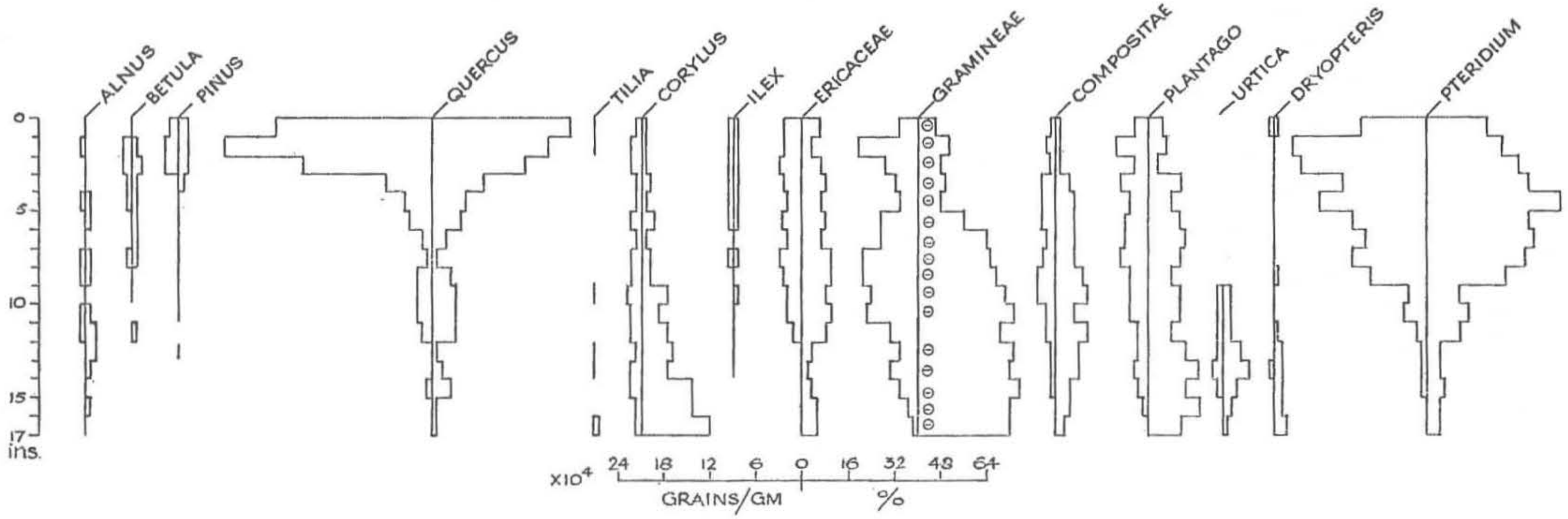
General

This is an unenclosed wood of *Quercus robur* but with a number of other species, e.g. *Acer pseudoplatanus*, *Quercus borealis*, *Tilia* × *vulgaris*, and *Fagus sylvatica*, though these are not so old as the dominant oak. The site was selected on account of the contrast between its soil and that under heathland outside the wood, a fact which suggested that this wood might be a relic of pre-heathland vegetation and its associated soil.

Pollen analysis

The pollen record falls into two main phases, an early one indicative of farming and a later one, persisting to the present, in which forest was dominant. Cereal pollen and weed pollen (*Plantago*, Compositae) are found at all depths, but it is remarkable that

MATLEY WOOD


ALNUS
BETULA
PINUS
QUERCUS
TILIA
CORYLUS
ILEX
ERICACEAE
GRAMINEAE
COMPOSITAE
PLANTAGO
URTICA
DRYOPTERIS
PTERIDIUM
0
5
10
15
17
ins.
X10⁴
24 18 12 6 0 16 32 48 64
GRAINS/GM
%

the Ericaceae never rise above subsidiary proportions. Therefore, while it is certain that the wood is not a relic, it is also apparent that the site has not been under heath.

In the lowest samples, *Corylus* reaches moderate proportions, but is dropping out. No other woody species are present in noticeable proportions, and the dominant vegetation is grass and associated herbs, including *Urtica*. At about 12 in. there is a slight increase of *Quercus* and *Pteridium*, and the Ericaceae increase from their hitherto very low values. Nevertheless, the grasses remain dominant, and continue so as *Corylus* fades right out and *Quercus* drops away again. *Pteridium*, however, increases rapidly, soon at the expense of the grasses, which fall away concurrently—a phase which suggests the abandonment of agricultural land. After a period of dominance of *Pteridium*, *Quercus* again increases, whether by natural regeneration or by planting cannot be said; it is perhaps significant that *Betula* and *Pinus* reached higher values between the *Pteridium* and *Quercus* phases, though they did not achieve dominance.

While it never rises above very low proportions, the pollen of *Ilex* shows a distribution confirming other evidence that it has only become important in recent times. It is noteworthy that though adjacent parts of the wood (100 yds. away) were pure beechwood, the *Fagus* pollen is scarcely represented in these analyses.

Soil characteristics

This soil shows little bleaching of the eluvial horizons like that of the *Calluna* heath outside the wood, which is also on Plateau Gravel, though considerably more stony. In appearance the profile is that of an acid brown forest soil (Plate VII, 1) showing, according to the A/T ignition profile, slight removal of iron from the upper layers. The pH of the top layers of the mineral soil is 4·4 (glass electrode).

The pollen analyses and the soil features agree in indicating that this soil has never been under heath vegetation. It has been used for agriculture for a long time, though there is no indication that it has ever been ploughed, unless the consistent presence of cereal pollen is taken as evidence. No statement can be made, from these data, about the possible manuring of the site.

The earliest pollen is almost certainly post-Bronze Age, as shown by the insignificance of *Tilia* and *Alnus*, and may be a good deal later than this. There may, therefore, have been a period when the soil pH was too high for pollen preservation; sufficient decalcification may only have taken place in relatively late times. Whether this implies earlier manuring practices or an initially more base-rich site it is impossible to say, and the anomalous condition of this piece of land in relation to its surroundings remains unexplained.

Site No. XXI. OAKHANGER—THE WARREN

Place

On The Warren, close by the Oakhanger–Bordon road, 8 miles SSW. of Farnham, Surrey.

National grid reference

SU/775356.

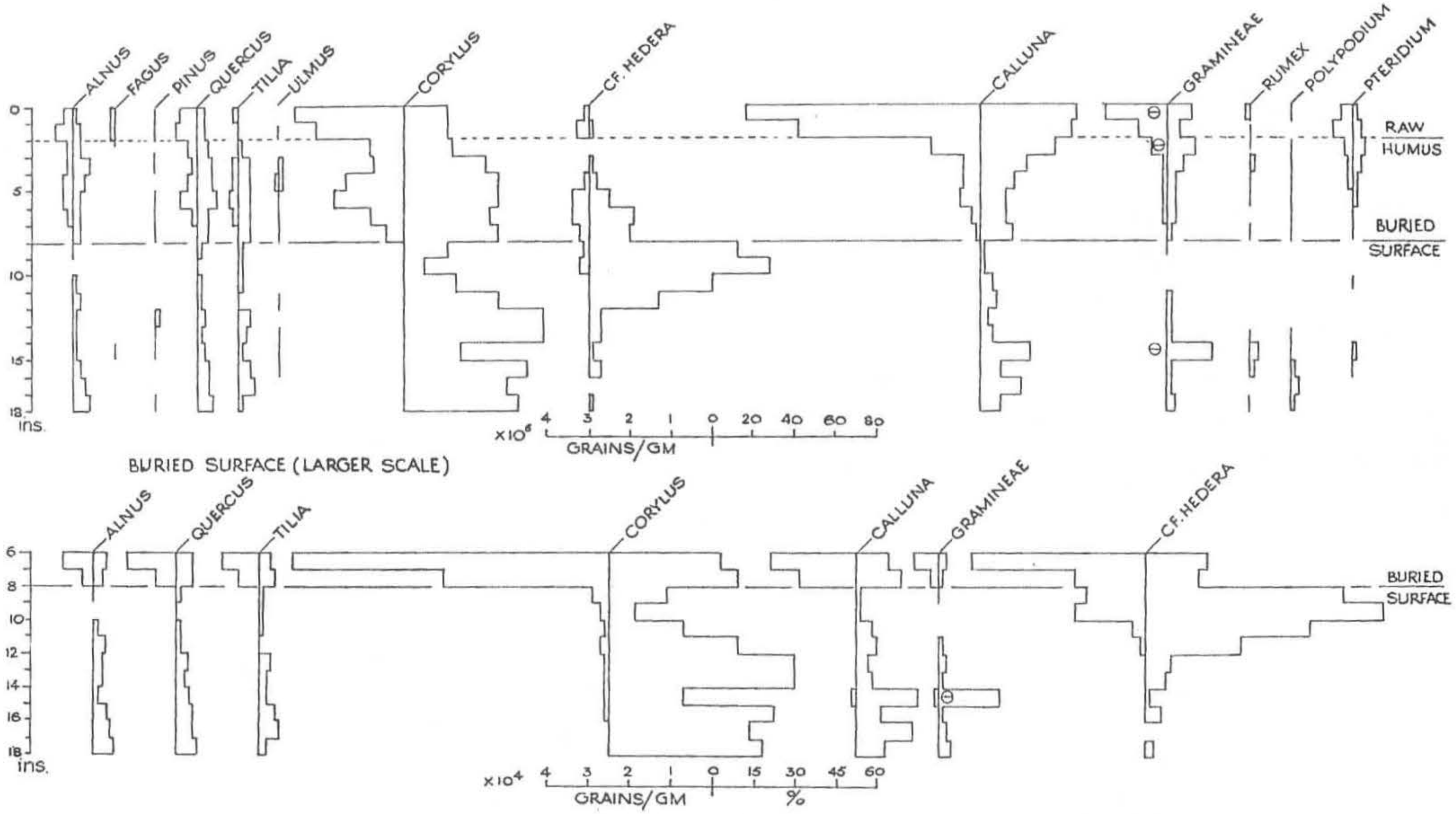
Geology

Cretaceous: Folkstone Beds of the Lower Greensand. The upper layer probably consists of material redistributed during the Post-glacial period.

Topography

Gently sloping to the NE. Altitude 280 ft. O.D.

OAKHANGER – THE WARREN
(COMPLETE PROFILE)



Present vegetation

Calluna heath, but much disturbed.

General

The site was investigated at the invitation of Mr. W. F. Rankine, who has already published interim reports of the archaeological work. The site has been dated by C^{14} determinations to about 4300 B.C., and is purely Mesolithic. For a full report on the archaeology and palaeobotany see (86).

Pollen analysis

It was revealed that a buried level occurred at 8 in., in which the dominant pollen was that of cf. *Hedera*. This poses similar problems to those met at Portesham (Site XXIII), but the Oakhanger site is of a much earlier date. In fact, in view of its occurrence within the Mesolithic, it appears less likely that the unknown species is to be regarded as a crop plant. That the level is of Atlantic date is indicated by the presence of *Alnus*, *Tilia*, *Quercus*, and *Ulmus* in the sand, both above and below the 8-in. level, while the association of flint artifacts of Mesolithic type and of charcoal datable to the same period corroborates the conclusion.

The complexities of the site as revealed by pollen analysis will not be discussed further here, except to comment that the occurrence of more recent species, notably *Fagus* and cereal grains in the 14–15-in. sample, can reliably be attributed to movement down a root channel.

Soil characteristics

The soil is a very well-developed humus–iron podzol, with a deep bleached layer and an unusually thick (20-in.) accumulation horizon, extending into the undisturbed Folkestone Sand which forms the subsoil (Plate II, 2).

The 8-in. level is not recognizable as such either visually or on the ignition profile, though in fact it occurs at the base of the A_1 horizon of the present soil.

An interesting feature of the ignition profile is the presence of traces of iron coloration in the upper part of the A horizon. It should be noted that though charcoals were present throughout the bleached layer, there was no sign of reddening of the sand in which they were found.

SITE NO. XXII. PONDHEAD

Place

The Northern section of Pondhead Inclosure, 1 mile ESE. of Lyndhurst, Hants.

National grid reference

SU/312075.

Geology

Eocene: Barton Sand.

Topography

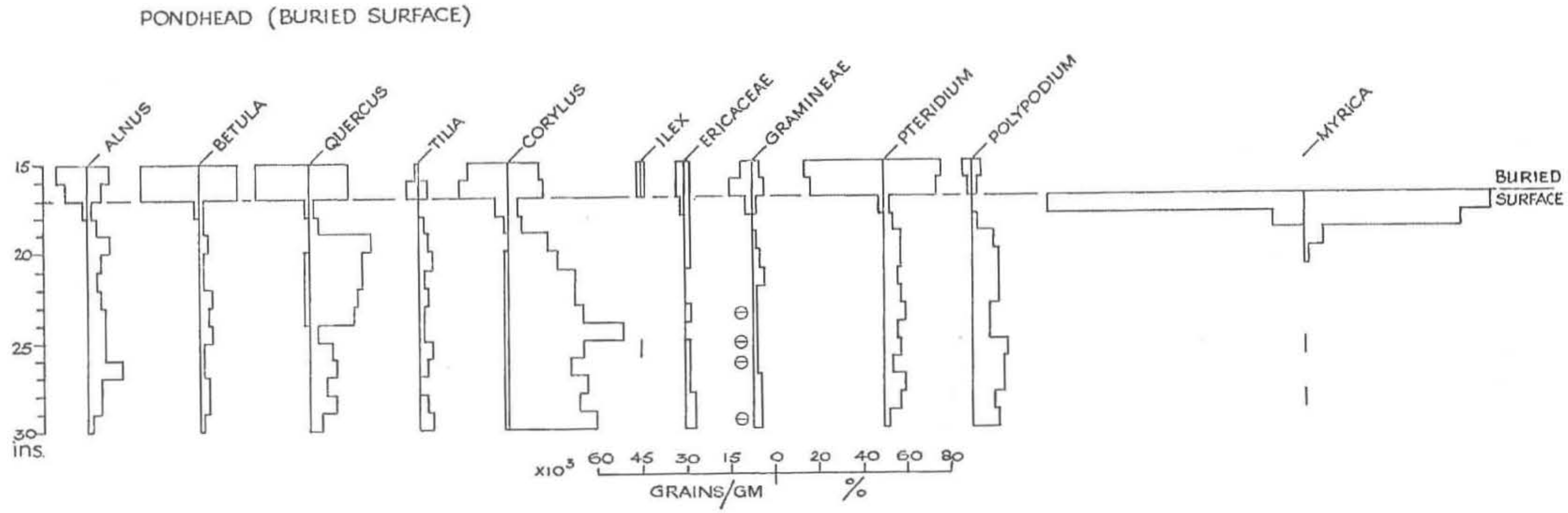
Slightly undulating but generally level site in the bottom of a broad, shallow valley. Altitude 100 ft. O.D.

Present vegetation

Quercus robur and *Castanea sativa*, planted A.D. 1810; relatively open beneath.

General

The site sampled was under the edge of the canopy of a *Castanea*, though *Castanea* was overall much less frequent than *Quercus* in the stand.


PONDHEAD (BURIED SURFACE)
ALNUS
BETULA
QUERCUS
TILIA
CORYLUS
ILEX
ERICACEAE
GRAMINEAE
PTERIDIUM
POLYPODIUM
MYRICA
BURIED SURFACE
15
20
25
30
ins.
x10³ 60 45 30 15 0 20 40 60 80
GRAINS/GM
%

Pollen analysis

There is clearly a buried level concealed in this soil and only revealed by the pollen analyses. A sharp change at 17 in. is seen in most of the curves in the diagram and is particularly emphasized by the sudden appearance of *Myrica*.

Before giving an interpretation of these curves, one point should be made. The *Castanea* pollen is present in very large quantity near the present surface, but it falls away rapidly with depth. However, it unexpectedly makes a reappearance, though in insignificant proportions, in the 21–30-in. zone. As this zone presumably predates the introduction of *Castanea*, since *Tilia* is consistently present throughout, it seems more likely that this is a contamination from higher up. Some confirmation of this is to be found in the sporadic occurrence of cereal pollen in this zone, while the *Pinus* curve shows a similar pattern. It should be noted that all these are mere traces, and this contamination cannot affect those curves in which the proportions at this level are equal to or greater than in the upper layers. It seems likely that the explanation is to be sought in a small root channel connecting the present surface layers with the deeper layers.

In the buried soil the pollen record indicates woodland conditions, with abundant *Corylus* and *Quercus*, the latter not being completely dominant (cf. Keston Camp, Site XIV). *Tilia* was consistently present in small amounts, and ferns (other than *Pteridium*) were more abundant than at any time since. This woodland phase was followed, apparently suddenly, by the dominance of *Myrica*, a change which could have been brought about by a rise in the water-table. In this situation this could have occurred by the increased level, or the damming, of a near-by stream, but it must be borne in mind that at Decoy Heath a similar *Myrica* level occurred under totally different topographical conditions.

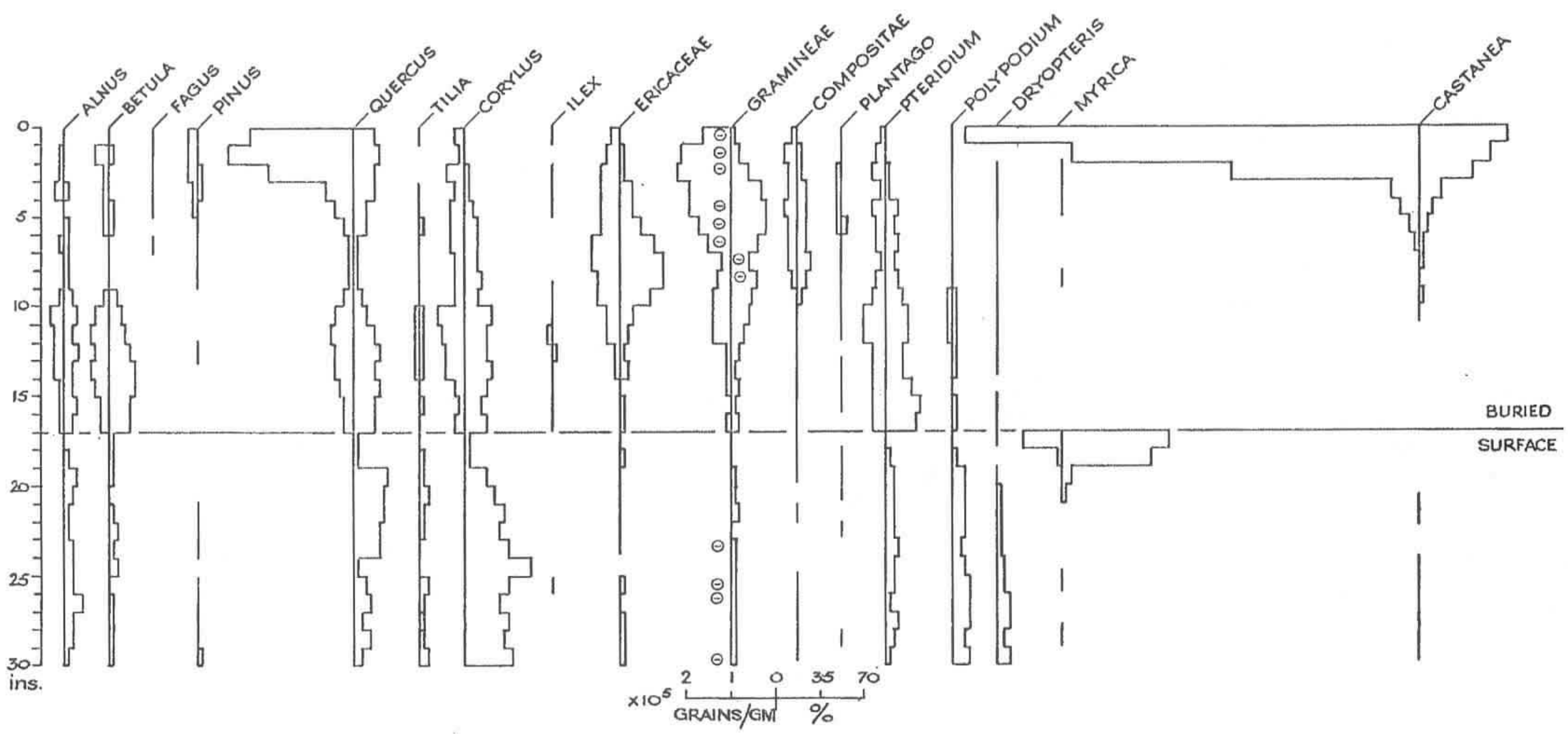
This *Myrica* community was apparently overwhelmed, probably by soil creep, and on the new surface 17 in. higher, a new forest growth sprang up, differing in certain features from that which had preceded the *Myrica* period. *Quercus* was present in about the same proportions, and *Corylus* was still abundant, though less so than previously. *Betula* and *Alnus*, however, both showed big increases, but were preceded both in time and dimension by *Pteridium*. *Ilex* also put in its first consistent appearance, but in small proportions.

Eventually this woodland phase broke down and was replaced by Ericaceae and grasses, though *Corylus* and *Pteridium* persisted in reduced proportions. The Ericaceae soon assumed dominance over the grasses, but the heath was eventually supplanted by a new grass phase in which the cereal pollen and that of Compositae and—to a lesser extent—*Plantago*, indicated farmland. This phase persisted until *Quercus* and *Castanea* became dominant, the result, as we know, of the planting of old fields in A.D. 1810.

Soil characteristics

The general profile is that of an intensively developed heath soil, comparable with the near-by White Moor (Site XIX) and the buried soil under The Ridge (Site XVIII) (see Plate VIII) and in itself sufficient to indicate a long heath phase. The upper 10–12 in., however, are not typical of heath podzol, consisting of mull humus, contrasting with the raw humus and the A horizon of the heath soil. The A/T ignition profile revealed an interesting and important difference between these humus horizons in relation to the iron content. In the heath soil (e.g. White Moor) there may be some iron in the raw humus, but little or none shows up in the mineral soil. In Pondhead, however, iron is obviously present throughout the mull layer (Plate VI, 4). This feature has also been recorded in other regenerating podzols, notably Suffield Moor—Birch (Site XXVII) and Keston Copse (Site XVI). There is no indication in any of these cases that iron-containing material has been added, e.g. in liming, marling, or fertilizing, but this possibility cannot be ruled out; the well-marked pollen stratification proves that the soil has not been ploughed. Superficially, the iron enrichment looks like a natural feature of soils undergoing regeneration. An obvious correlation is with the nature of the rooting of the new vegetation, particularly its ability to tap the iron-rich subsoil.

PONDHEAD (COMPLETE)



In all these cases, however, a grassland phase has probably intervened between the heath stage and the present woodland, and it cannot yet be said whether this rejuvenation of the iron content started in the grass phase or whether it only occurred when the trees colonized the site.

There is some slight indication of the buried surface in the A/T ignition profile, marked by a faint change in colour, but this may be secondary. It is not thought that in this case there is any significance in the association of this surface with the top of the B horizon, because in an earlier and less intensive sampling the *Myrica* peak came in the middle of the A_2 horizon, 14 in. below the present surface and about 6 in. above the top of the B horizon.

An unusual feature of this profile, which might be associated with its double origin, is the big discrepancy between the deposition of humus and the deposition of iron, as revealed by the A/T ignition profile. In this respect it contrasts with both White Moor and the buried heath soil of The Ridge. This suggests that the soil was already podzolized when the original surface was buried, but that this podzol involved the movement of iron rather than humus; the massive humus deposition would therefore be seen as a result of soil genesis after the initial podzolization. This may be confirmed by comparisons of prehistoric and recent soils, such as Burley Barrow (Site III) and Burley Heath (Site IV)—which occur on geologically the same parent material as Pondhead—from which it is clear that the prehistoric soil, though well bleached of iron-colour, shows little humus accumulation in the B horizon.

We cannot be sure whether the material which covered the buried layer at Pondhead was initially iron-rich, though the likelihood is that it was not. (If pollen was present in the covering material, the amount would be equivalent to that in the buried soil, which would be insignificant compared with what was subsequently deposited in it. Moreover, the spectra show important and significant differences, and *Polypodium* is especially significant in this respect.)

Site No. XXIII. PORTESHAM

Place

Immediately S. of the Hardy Monument on Black Down, 5 miles WSW. of Dorchester, Dorset.

National grid reference

SY/613876.

Geology

Eocene: Gravels of the Bagshot Beds.

Topography

The barrow stood on the crest of a ridge facing S. Altitude 750 ft. O.D.

Present vegetation

Grassy heath.

General

The barrow stood on the edge of a deep gravel pit which had encroached on the mound. After excavation the barrow was destroyed by bulldozing. A full report of the excavation, together with pollen analyses, was published by Thompson and Ashbee (113).

Pollen analysis

See report included in the above-mentioned paper.

Soil characteristics

The soil beneath the barrow has not been completely recorded in descriptions and photographs. It is clear, however, that it was a strongly developed podzol (A/T profile of upper layers) with an eluvial horizon varying from 1 to 2 ft. in depth, but extending in 'pipes' down to several feet. The B horizon was poorly developed, both beneath and outside the barrow.

The mound itself was made up of two main parts: a core of turves, surmounted by a layer of gravel several feet thick. The pollen analyses showed that this gravel was of subsoil origin and it is therefore especially noteworthy that the soil which has developed in it since the mound was built is a humus–iron podzol. This is shown clearly by the A/T profile of the barrow surface. The ignition profile reveals that leaching of iron is not as complete as in the buried soil, but there is, nevertheless, iron accumulation in the B horizon.

It is apparent from the pollen analysis that the post-barrow flora has never been true *Calluna* heath but grassy heath in which the proportion of ericaceous species has gradually been increasing. It is all the more remarkable, therefore, that the soil of the mound is so markedly podzolized.

Site No. XXIV. RALPH CROSS

Place

At Rosedale Head, 10 miles N. of Kirkby Moorside, Yorks., N.R.

National grid reference

NZ/676020.

Geology

Jurassic: Grey Limestone Series of the Lower Oolite. This very variable formation here takes the form of a blue shale, giving an acid clayey soil.

Topography

On dead ground on the watershed between Rosedale and Westerdale, but dominated by a gentle rising slope to the W. Altitude 1,400 ft. O.D.

Present vegetation

Calluna heath, recently burned.

General

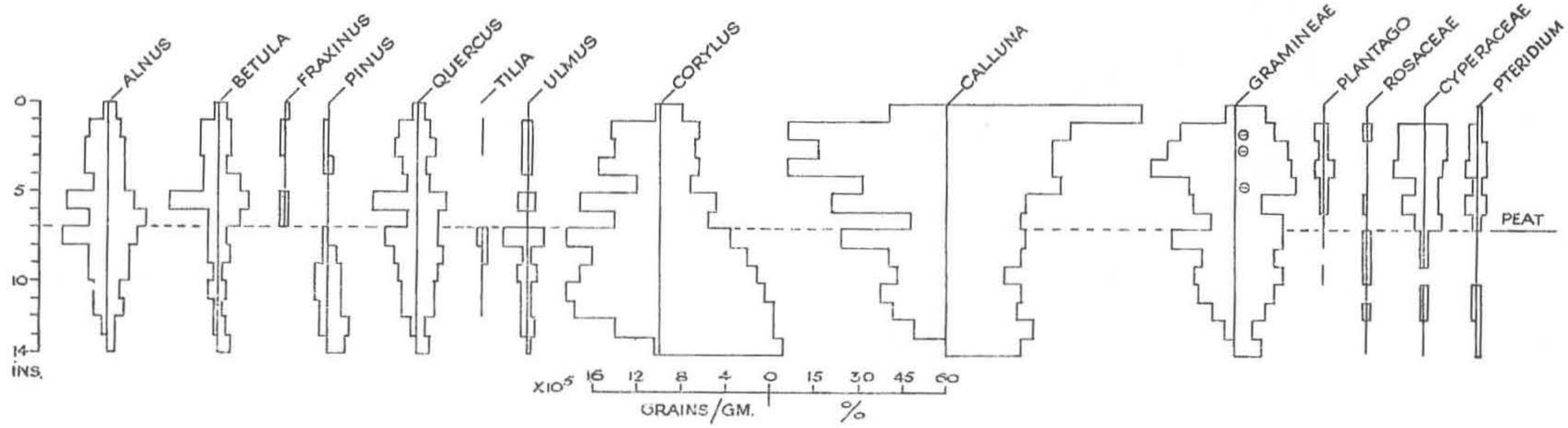
Though erosion of the moorland was taking place in the neighbourhood, this site was apparently unaffected.

Pollen analysis

Here the question arises of dating the transition from mineral soil to peat. The uppermost inch of the organic layer is distinct from the rest in containing very little but *Calluna* pollen, and obviously represents the influence of the present moor vegetation. It seems probable that moor fires will consume this layer repeatedly, but the peat beneath contains a much higher proportion of woody species, from which one assumes that it does not burn, presumably because of its wetness.

Though *Calluna* is still dominant in this lower part of the peat, the grasses are more abundant, together with *Plantago* and cereal pollen, indicating that this wet phase is Sub-atlantic (note the Cyperaceae). Of the woody plants, *Corylus* and *Alnus* are most abundant, while *Fraxinus*, too, gives a continuous curve, which is in accord with Godwin's observations (53) of its consistent record at high altitude. *Quercus* and *Betula* are also significantly represented, but *Tilia* is almost absent, as one would expect in the Sub-atlantic. *Ulmus*, however, another characteristic tree of the mixed oak forest of

RALPH CROSS



ALNUS
BETULA
FRAXINUS
PINUS
QUERCUS
TILIA
ULMUS
CORYLUS
CALLUNA
GRAMINEAE
PLANTAGO
ROSACEAE
CYPERACEAE
PTERIDIUM
PEAT
0
5
10
14
INS.
X10^5 16 12 8 4 0 15 30 45 60
GRAINS/GM.
%

the climatic optimum, shows up surprisingly well, but this fits in with a number of observations indicating that *Ulmus* has persisted until relatively recent times. In fact, Barry (4) gives historical record of this species in the Cleveland Hills, likewise *Fraxinus*. The sporadic occurrence of grains of *Fagus* and *Carpinus* finally prove the Sub-atlantic date of the peat.

This being so, it would seem reasonable to attribute the upper layers of the mineral soil to the immediately preceding period. This profile does not exhibit any discontinuity between peat and mineral soil; in fact, both the percentages and frequencies show a surprisingly smooth transition, a fact which may not be unconnected with the somewhat indeterminate nature of the transition visible in the soil profile itself.

However, certain distinct changes do occur. *Tilia* is present in measurable quantity, but *Plantago* and the Cyperaceae are much reduced. These differences suggest that the transition was not entirely a gradual one, but was associated with climatic change, and possibly also with cultural changes.

The lowest pollen spectra show a superabundance of *Corylus*, which shares dominance with *Calluna*; *Pinus* is the main tree species, though *Betula* also flourished on a small scale. This might be regarded as a Boreal flora, especially since it is followed by a general increase of *Alnus*, *Quercus*, *Tilia*, and *Ulmus*, but there is nothing particularly diagnostic about this flora. *Pinus* and *Corylus* were both present on these hills in the Sub-boreal, as the macroscopic remains from Harwood Dale Bog show (Whitaker, 121), and the increase of forest trees at the expense of *Corylus* is a likely result of either increasingly wet conditions, or a cessation of anthropogenic influence, or both together. *Tilia* persisted into the Sub-boreal, and its low percentages here, particularly when compared with the high values which it seems to have reached in Atlantic times, would agree with a Sub-boreal dating. *Ulmus*, it seems, has little diagnostic value. The most significant single factor, however, weighing in favour of allocating this pollen to Zone VII*b* is the grass curve. The steady increase of grasses, at a time when forest too was expanding, suggests that human as well as climatic factors were at work, and this virtually eliminates the transition from Zones VI to VII*a*.

Thus the landscape is seen first as one in which *Corylus* is widely dominant, though open areas with *Calluna* occur in mosaic, a typical early anthropogenic pattern. As time goes on the *Corylus* gradually recedes, and the grasses make headway, together with some of the forest trees. The increased proportion of the latter may, however, be a direct result of more open conditions, allowing pollen transported from the valleys to contribute to the hill-top pollen rain. At the transition to Zone VIII there was still a good deal of *Corylus* left on these hills, but after a temporarily increased influence of woody species, the hill-top conditions changed to a wet grassy heath from which woody plants were virtually excluded. Their influence was felt from the valleys and perhaps more from the gills and ravines which cut into the hills, and which even today carry scrub *Sorbus*, *Betula*, and *Quercus*, though little sign is seen of the other forest species mentioned by Barry. In fact at some stage in historic time the moorland has ousted all other influences, as seen in the spectrum from the top sample of this profile.

Soil characteristics

As mentioned above, the boundary between the peat and the mineral soil is indistinct, but the average depth of peat is 7–8 in. The A/T ignition profile shows that this material is relatively iron-rich.

The mineral soil is a sticky clay, passing into grey-blue clay in which many small dead roots run in orange channels. The surface vegetation must be within rooting reach of an iron-rich zone, at any rate at certain seasons. The first 5 in. of the mineral soil are devoid of iron, but below this the amount of iron gradually increases. There is no visible B horizon, and the soil would be classified as a peaty gley.

A short distance away the parent material changes abruptly to a sandy loam, and with no visible change in the vegetation the soil type becomes a thin iron-pan podzol.

Site No. XXV. REASTY TOP BARROW

Place

Near the top of Reasty Bank, 6 miles NW. of Scarborough, Yorks., N.R.

National grid reference

SE/965943.

Geology

Jurassic: Lower Calcareous Grit (non-calcareous in the soil-forming layer) of the Middle Oolite.

Topography

On the dipslope behind the N. scarp of the Hackness outlier. Very gentle slope to the S. Altitude 650 ft. O.D.

Present vegetation

Calluna heath, recently ploughed and afforested.

General

This very small barrow was undetected until deep ploughing revealed it, at the same time destroying it. Fragments of a Middle Bronze Age urn were excavated by W. H. Lamplough.

Pollen analysis

As the mound had been wrecked by the plough it was only possible to sample through the old soil surface. The base of the mound showed strata of black humic material, presumably some form of turf, suggesting that the lower part of the mound at any rate was made up of sods. The highest sample was taken from such a dark band, and 3 in. lower another was encountered which was assumed to be the buried surface, since below it there was a shallow immature podzol.

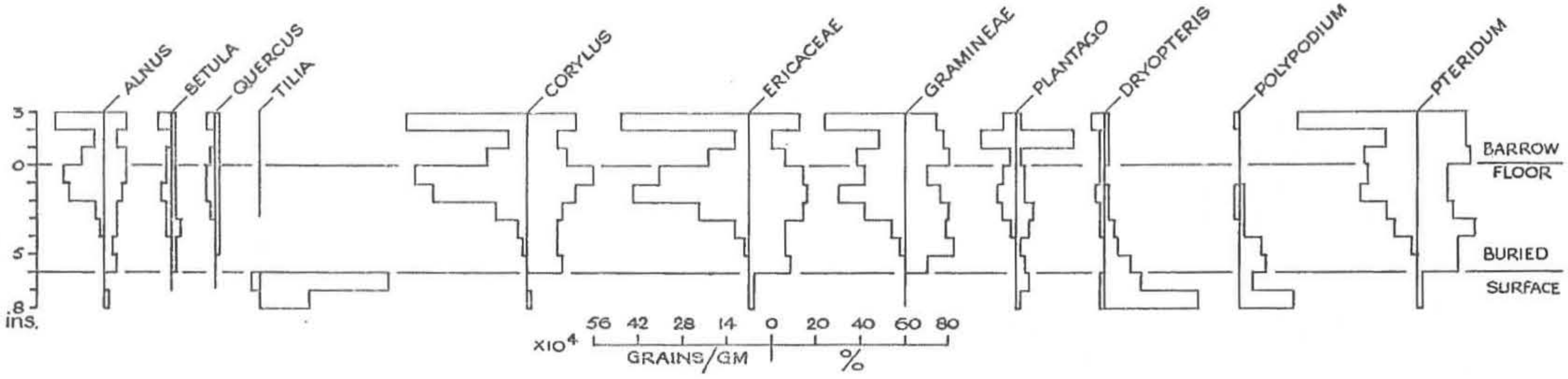
This is confirmed by the pollen analysis, which clearly shows the barrow floor. The uppermost turf line closely resembles it in spectrum, though it is somewhat richer in *Pteridium*. At 6 in. below the barrow floor there is a complete break in the pollen curves, clearly representing a buried soil pre-dating the barrow itself. The feature of the spectrum in this buried soil is the enormous percentage of *Tilia*, namely 58 per cent. of all the pollen; the only other plants represented are ferns, and the combination of these resistant types suggests that this is the remains of a more varied flora which has undergone extensive breakdown. That this spectrum has not been derived from the upper part of the soil, however, is proved by the big increase in the absolute frequency of *Tilia* and the fern spores.

The upper layers of the prehistoric soil show only slight changes, and one would surmise that the pollen record does not cover a very long period of time. The fern spores, and especially *Pteridium*, are of importance at first, combined with *Corylus*, Ericaceae, and grasses, giving once again the picture of a mosaic of *Corylus* woodland and open stretches. In the course of time the ferns dropped out, excepting *Pteridium*, the grasses flourished, together with weeds such as *Plantago*, and the Ericaceae increased their influence. Finally, however, before the barrow was built, woody species, notably *Corylus* and *Alnus*, showed a marked increase, while the heath species receded somewhat.

Soil characteristics

The soil was an immature thin iron-pan soil with 3 or 4 in. of intensely leached A_2 horizon, overlying a faint humic accumulation and a slight thin iron-pan. Since there is a buried level coincident with the level of accumulation, and this possibly had

REASTY TOP BARROW



(26)

a different initial iron content, it is difficult to gauge the degree to which iron had accumulated. This is a good example of a B horizon forming at an interface. It is also one more instance of a prehistoric soil with no more than a suspicion of organic accumulation in the B horizon.

It was recorded that a fire-reddened stone was found in the leached layer at 3–4 in. below the buried surface.

Site No. XXVI. SPRINGWOOD BARROW

Place

6½ miles NW. of Scarborough, Yorks., N.R.

National grid reference

SE/953939.

Geology

Jurassic: Lower Calcareous Grit of the Middle Oolite. This material is non-calcareous in the soil-forming zone.

Topography

On a very gentle slope to the S. Altitude 630 ft. O.D.

Present vegetation

Recently established coniferous plantation on *Calluna* heath.

General

The area as a whole was ploughed and the barrow damaged by ploughing. The bulk of the barrow has now been destroyed. This was the first barrow to which the present techniques were applied; the results have already been published (31).

Pollen analysis

The analyses were carried out before standard techniques were evolved, so that only percentages are available. The results have been fully discussed in the above-mentioned paper.

Soil characteristics

The only representations of the barrow soils which can be presented here are the A/T profiles. From the full profile the soils developed in the barrow floor and in the mound itself are clearly seen. The first is apparently a brown forest soil with slight evidence of iron movement from the upper few inches (Plate IV, 2); a second section through the buried soil under another part of the mound showed rather more intense leaching (Plate IV, 3)—even though at this point there was less *Calluna* in the pollen spectrum. Neither showed any marked accumulation of either iron or humus, and it is apparent that this soil was showing the very early stages of degradation.

In contrast, the soil developed in the mound, which was probably composed of topsoil, was a humus podzol. The original surface was at the present 5 in. mark, but it was raised, still within the Bronze Age, to its present level. The present soil, therefore, has been developing from the present surface for about 3,000 years. The material was already depleted of iron—being topsoil—but further stratification of iron has taken place, while a distinct humus B horizon is seen between 7 and 10 in. (The dark staining in the 16–18-in. samples is due to charcoal which was encountered at this level.)

SITE No. XXVII. SUFFIELD MOOR—BIRCH

Place

In patch of woodland near Thieves' Dykes, 5 miles NW. of Scarborough, Yorks., N.R.

National grid reference

SE/972929.

Geology

Jurassic: Lower Calcareous Grit of the Middle Oolite. It gives non-calcareous soils.

Topography

Level. On a plateau overlooking the head of a steep valley. Altitude 600 ft. O.D.

Present vegetation

Scrub woodland of *Betula pubescens*, 60 years old, with some older oaks scattered through it.

General

See (27) for site details. The upper layers of the soil were examined for pollen as reported in that paper, but an analysis of the type given below was not possible at that date.

Pollen analysis

This site provides yet another example of a buried level, and again one at which the B horizon has subsequently developed. Below the 6-in. level *Alnus*, *Corylus*, and ferns are the main groups represented. The *Dryopteris*-type spores decrease up the profile, whereas those of *Pteridium* increase in proportion. *Tilia* is consistently present in small numbers, but *Quercus* is even less prominent. There is a small but steady representation of grasses, but the Ericaceae are scarcely represented. The small numbers of this group, and of cereal pollen below the pan, can reasonably be attributed to downwash before the pan finally closed, or perhaps even since it became disrupted.

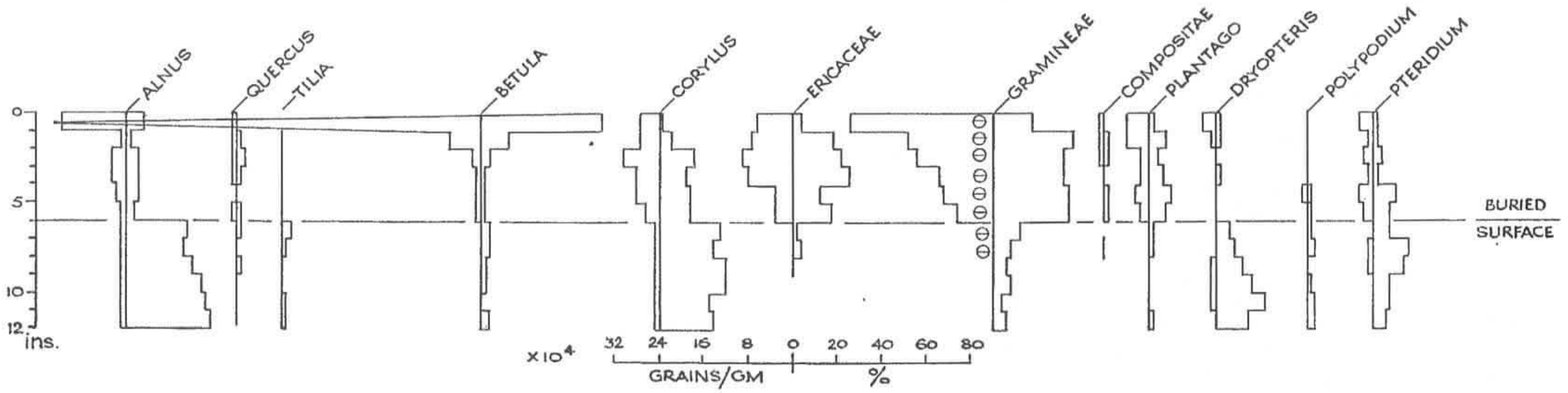
Above the pan the contrast is great. The grasses are predominant, and pollen of *Plantago*, Compositae, and cereals is found throughout. The Ericaceae curve increases to a peak at 2–4 in. and then dwindles again, being succeeded by an even greater development of the Gramineae, until in the top inch they yield to the explosive spread of *Betula*. Of the other woodland species, *Corylus* is much less predominant than in the soil below the pan, but it maintains moderate proportions until it drops in the top two samples. *Alnus* is even more completely eclipsed, though showing a surprising return in the top sample. *Quercus* and *Tilia* are both consistently present in small numbers, the latter as a mere trace. Of the fern spores, *Dryopteris* and *Polypodium* have only a shadow of their importance in the subsoil, though *Dryopteris* shows an increase in the recent *Betula* phase. *Pteridium* is not restricted to the same extent, though it never achieves important proportions.

While the flora of the subsoil must be regarded as primarily a woodland one, that above the pan shows predominantly open conditions with grasses dominant, though hazel woodland has probably been in the vicinity throughout much of the record. The heath species increased in proportion and then fell away again, but it seems doubtful whether pure *Calluna* heath could have become established, in view of the consistently high representation of grasses.

Soil characteristics

This site has already been discussed in some detail (27). The soil is somewhat variable, having in places a well-defined but disrupted thin iron-pan, and elsewhere little sign of the pan as a continuous layer, though it can be seen intermittently (Plate

SUFFIELD MOOR-BIRCH



V, 3). The site may be compared pedologically with Suffield Moor—Heath (Site XXVIII) and from this comparison it is apparent that the profiles have been almost identical at one time, but that in this site regeneration has taken place. The bleached layer has become humus-rich, and the A/T ignition profile (Plate VI, 2) shows the re-incorporation of iron as found at Pondhead (Site XXII) and Keston Copse (Site XVI).

The subsoil is an undifferentiated iron-rich sand.

The earlier conclusions about the causes of soil regeneration must be modified in the light of the pollen analyses, though the sequence of processes remains unaffected. It is apparent, however, that it would not be justifiable to attribute the regeneration entirely to birch, since a grass phase intervened between it and the earlier grass-heath vegetation.

SITE No. XXVIII. SUFFIELD MOOR—HEATH

Place

Within the Thieves' Dykes, 5 miles NW. of Scarborough, Yorks., N.R.

National grid reference

SE/972932.

Geology

Jurassic: Lower Calcareous Grit of the Middle Oolite. It gives non-calcareous soils.

Topography

Level plateau site. Altitude 600 ft. O.D.

Present vegetation

Calluna heath, being invaded by *Betula*.

General

This site serves as a basic comparison with Reasty Top Barrow (Site XXV), Suffield Moor—Birch (Site XXVII), and Suffield Moor—Pine (Site XXIX). See (27).

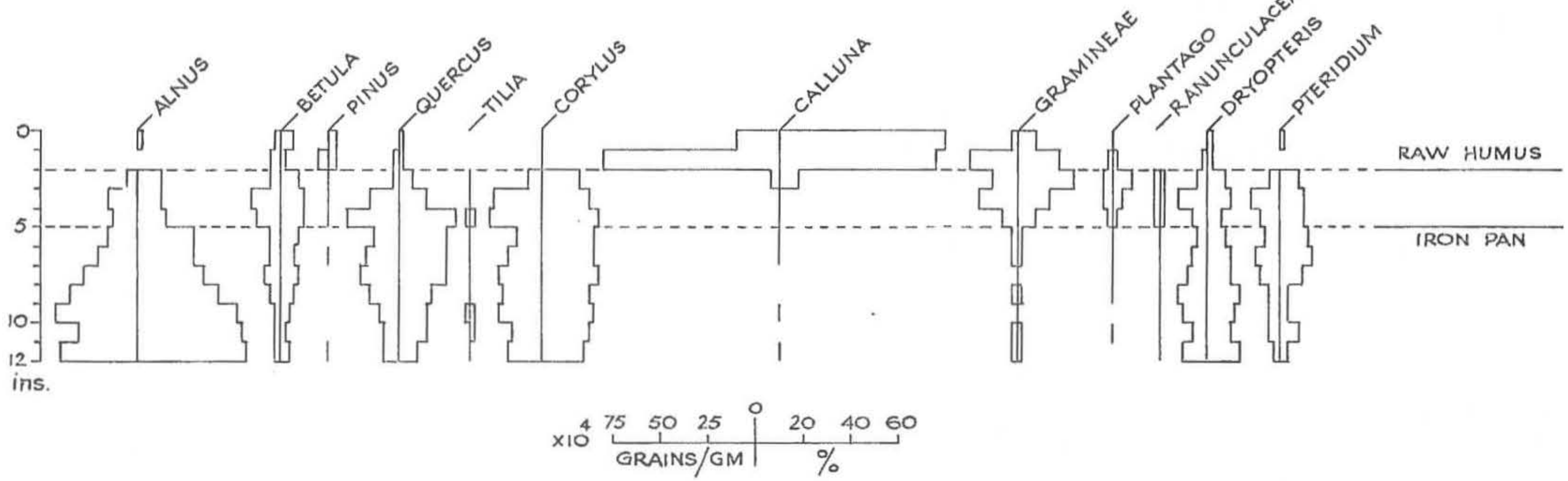
Pollen analysis

The raw humus layer of the soil shows the absolute dominance of *Calluna* on this site, though grass pollen is rather more abundant in the lower inch—perhaps a reflection of the succession after a burn. The small influence of tree species is most striking, considering that *Quercus* and *Betula* are flowering within 30 yds. to windward of the site, and a large block of pine lies 100 yds. to the E. Other tree species within ¼ mile of the site are *Fagus*, *Fraxinus*, *Corylus*, *Sorbus aucuparia*, *Larix*, *Ilex*, and *Salix*.

Samples were taken to a total depth of 12 in., but it is apparent that the counts could have been continued below this if samples had been available. The iron-pan at 5 in. causes very minor interruption in the curves, so that they can be regarded as essentially continuous.

At 12 in. *Alnus* and *Corylus* are the principal pollens present, the former reaching an unusually high percentage for this species. The only other significant group is the *Dryopteris*-type fern spores. Gradually, however, *Alnus* diminishes, while *Betula* and *Pteridium* become more abundant, *Corylus* maintaining a moderate proportion throughout. At the pan level the grasses come into prominence and thereafter play an increasing part, accompanied by *Plantago* and the Ranunculaceae. Of the woodland species, *Corylus*, *Betula*, and *Alnus* are still well represented, though the last-named occurs at less than a quarter of its percentage in the lowest layers of the subsoil. *Tilia* has been consistently present up to and just above the pan, but after that it occurs as a trace only; the ferns are present throughout in moderate proportions, with *Pteridium* in particular maintaining its position.

SUFFIELD MOOR- HEATH



The most striking feature of the whole profile is the contrast between the enormous preponderance of *Calluna* in the raw humus and its very poor representation in the top layer of the mineral soil. This discontinuity doubtless represents a long period of time, but it is apparent that when raw humus started forming the vegetation bore little resemblance to what we see there now. Once again there is the now familiar picture of a mosaic of woodland and open ground in which the grasses were the main dominants.

Soil characteristics

The soil is a shallow thin iron-pan podzol of a type not uncommon on these moors (Plate V, 2). The raw humus is seen to contain a good deal of iron, whilst the leached layer beneath it is humus-stained throughout and iron-free (Plate VI, 1). There is a clear-cut band of iron deposition, but there is no massive accumulation of organic matter. This feature is somewhat variable in this district, many profiles showing no visible organic B_1 horizon at all, while others show up to 2 in. of such a layer overlying the iron-pan.

SITE No. XXIX. SUFFIELD MOOR—PINE

Place

A triangular-shaped plantation at the SE. end of Suffield Moor, 5 miles NW. of Scarborough, Yorks., N.R.

National grid reference

SE/973932.

Geology

Jurassic: Lower Calcareous Grit of the Middle Oolite, giving rise to non-calcareous soils.

Topography

Approximately level plateau site. Altitude 620 ft. O.D.

Present vegetation

Coniferous plantation, mainly *Pinus sylvestris* and some *Larix decidua*, aged about 100 years (now felled). Area about 12 acres.

General

This site may be compared with Suffield Moor—Heath (Site XXVIII) and Suffield Moor—Birch (Site XXVII), which are both close by. See (27).

Pollen analysis

No complete analysis of this site has been made. A comparison of the curves for *Pinus* and Ericaceae through the raw humus layers reveals the superimposition of *Pinus* raw humus upon the old heath raw humus. This can be demonstrated simply in a table:

Depth (in.)	*Percentage*		*Total count*
	Pinus	*Ericaceae*	
0–1	67·8	4·8	273
1–2	80·5	5·8	811
2–3	75·2	12·3	779
3–4	58·2	29·8	1,267
4–5	12·9	80·4	1,405

Soil characteristics

The soil is essentially similar in appearance to the heath profile of Site XXVIII with the additional layer of 2–5 in. of pine litter lying upon the still-visible 1 in. of *Calluna* raw humus (Plate V, 4).

There is no sign of regeneration of the soil in the manner observed in the Suffield Moor—Birch soil.

SITE No. XXX. TROUTSDALE

Place

$7\frac{1}{2}$ miles due W. of Scarborough, Yorks., N.R.

National grid reference

SE/920887.

Geology

Jurassic: Lower Calcareous Grit (non-calcareous in the soil-forming layer) of the Middle Oolite.

Topography

On steep valley-side, facing E. Altitude 600 ft. O.D.

Present vegetation

Deciduous woodland, including *Quercus robur, Acer pseudoplatanus, Fagus sylvatica, Betula pubescens, Sorbus aucuparia, Ulmus glabra, Fraxinus excelsior.*

General

This scarp-edge woodland passes into dense *Calluna* heath at the top of the slope, and until recently the plateau was covered with old *Calluna*. The plateau has now been ploughed and planted up by the Forestry Commission under the name Wydale Forest.

It was apparent that the soil of this hill-side was heterogeneous, and in places a good deal of charcoal may be found below the humus layer. The soils of the upper slopes are podzols, but further down unbleached soils may be found.

Pollen analysis

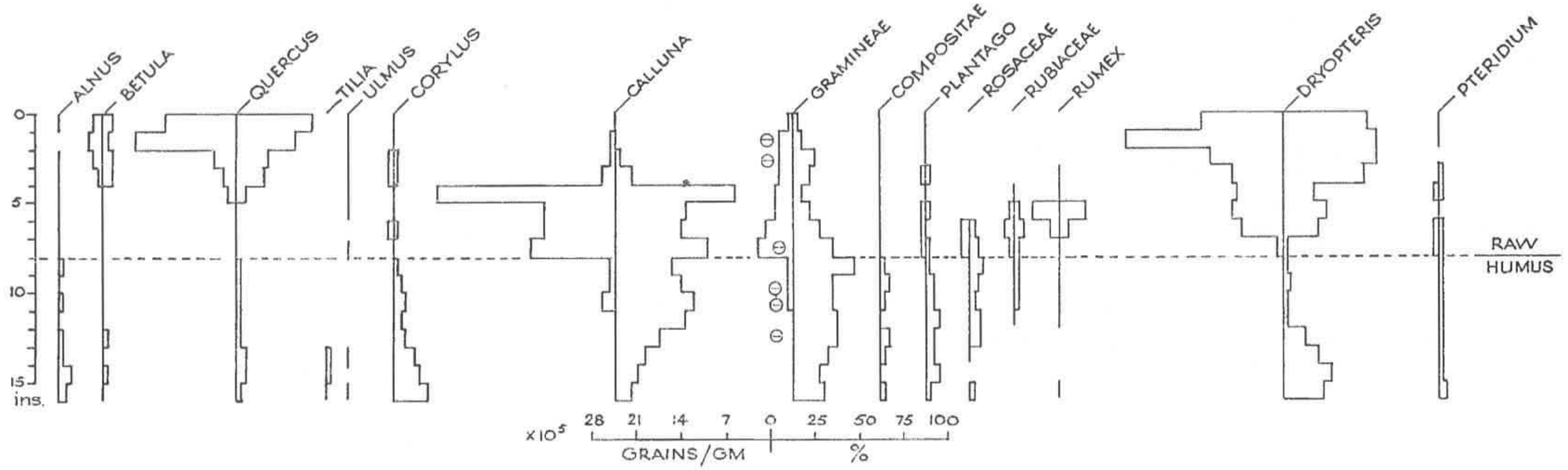
This profile falls into the pattern we have come to regard as normal for acid soils. There is a deep layer of raw humus clearly made up of organic matter from the present forest, accumulating on top of an undisturbed layer of heather raw humus, the latter some 4 in. thick.

The mineral soil of this profile shows traces, in its lowest layers, of an earlier woodland phase, in which *Alnus, Betula, Quercus, Tilia, Ulmus,* and *Corylus* figure, together with ferns. This gives way through grasses to grass-heath, and the association of cereal pollen and weed pollen in the upper layers points conclusively to agricultural influences. Since *Tilia* and *Alnus* are not represented in these upper layers, no more can be said than that the main agricultural influence was post-Bronze Age.

Soil characteristics

The soil is a thin iron-pan soil unusual only in its deep A_0 horizon; this has been shown, however, to be of double origin. The A_2 horizon is strongly bleached, and is underlain by a well-developed B horizon, marked by a humus-accumulation layer of strong development and very variable thickness, and thin indurated iron-pan. Such variability in the profile is commonly found in the scarp soils.

TROUTSDALE (1957)



SITE No. XXXI. WHITE GILL—STONY RIGG

Place

On the moors at the head of Westerdale and 9 miles SSE. of Guisborough, Yorks., N.R.

National grid reference

NZ/639026.

Geology

On the Estuarine Beds of the Lower Oolite.

Topography

At the head of a valley, below the hill-crest but above the spring line. Aspect NE.; altitude 1,250 ft. O.D.

Present vegetation

Eroded Callunetum ('fat moor'). Only isolated tussocks left, perched on peaty humus, $1\frac{1}{2}$–2 ft. high.

General

Mesolithic microliths are emerging from the junction of the mineral soil and the superimposed organic layers as the moor erodes. They can be picked up in considerable quantity. This section was chosen at a point where microliths were *in situ*. They were associated with charcoal of *Quercus*, *Alnus*, *Betula*, and *Corylus*.

Pollen analysis

A series of samples was taken running both upwards and downwards from the level at which the microliths were emerging, from +5 in. to −10 in. In addition, a bulk sample was taken in the *Calluna* tussock, from 6 to 12 in. above the flint line.

There is a higher frequency of pollen in the humus layers than in the mineral soil, which has necessitated plotting the two sections of the profile on different frequency scales.

The lowest samples show high percentages of grass pollen and little else, and it seems justifiable to equate this with a Pre-boreal phase. Sporadic grains of herbs. absent from the higher samples, occur here and support this conclusion. If it is correct this is the earliest recorded soil pollen apart from the Late-glacial fraction in the buried level of Cock Heads (35).

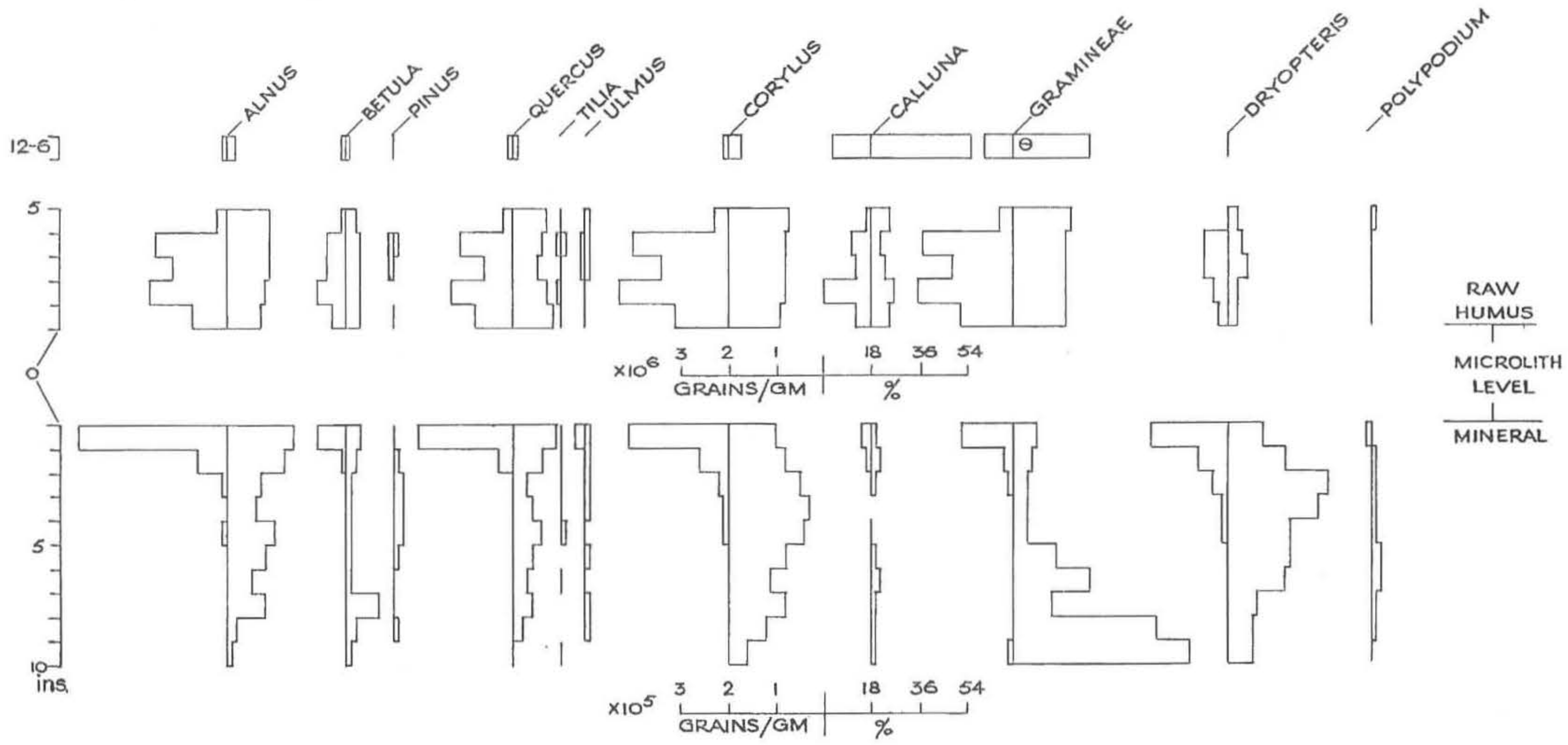
The grasses then dwindle and the pollen of woody species begins to appear, notably *Corylus*, *Alnus*, and *Betula* and to a lesser extent *Quercus*. Small quantities of *Pinus* and *Ulmus* also begin to appear consistently, suggesting that this represents the Early Boreal.

From 5 in. upwards the grasses reach their nadir, but the woody species continue to increase slowly. *Corylus* in particular reaches its peak, and there is a feeble maximum of *Pinus* at 4–5 in. *Tilia* becomes consistently present. This trend of increase in the proportion of forest species is accompanied by a marked increase in *Dryopteris*-type spores, culminating at 2–3 in. Thereafter they fall away, as does *Corylus* too. This suggests the passage through the Middle and Late Boreal, and when from 2 to 0 in. *Alnus* and *Quercus* become their most prominent, it seems likely that they represent the Atlantic period.

The flint industry is, therefore, to be allotted to this climatic zone, and is comparable in this respect with Oakhanger—The Warren (Site XXI).

Above the flint level the soil is purely organic. The pollen analyses show certain abrupt changes compared with those of the mineral horizons. Apart from the generally higher frequency, there is a drop in the *Alnus* and especially the *Dryopteris*

WHITE GILL-STONY RIGG



(30)

percentages, but there is a distinct increase in the proportions of grasses, *Calluna*, and to a lesser degree *Betula* and *Corylus*. This increase in light-demanding species may suggest the influence of man on the forest. Whereas in the 0–1-in. sample the NTP/TP percentage was 38·6, indicating closed forest conditions, the ratio for 5–0 in. was 103·9, which shows that the forest was no longer dense.

The two layers show the following comparative spectra based on the tree pollen alone:

Depth	*Alnus*	*Betula*	*Fraxinus*	*Pinus*	*Quercus*	*Tilia*	*Ulmus*	*Corylus*	*NTP*	*ΣTP*
0–1 in.	51·9	10·1	. .	0·5	33·9	0·5	2·6	35·4	38·6	189
5–0 in.	44·3	14·8	1·4	1·2	33·8	1·7	2·7	61·9	103·9	515

It is to be doubted whether these differences are such as to represent a change in climate; they would be fully explicable on anthropogenic grounds. The diagnostic species such as *Tilia* and *Ulmus* remain virtually unaltered, and *Alnus*, although less, is still the main component of the spectrum. Only the appearance of *Fraxinus* might suggest the Sub-boreal period. On the other hand, the analyses of the turves from the Burton Howes (Sites VI and VII), presumably of Sub-boreal age, showed a very similar forest composition; in fact *Alnus* was even better and *Quercus* correspondingly less well represented. It seems that the Zone VII*a*–VII*b* transition was not marked by any variation in the major components of the mixed forest.

The bulk sample from the *Calluna* tussock (12–6 in.) merely serves to show the contrast between the prehistoric and the more recent humus layers, in which *Calluna* and Gramineae have completely ousted the woody species.

Soil characteristics

The soil beneath the flints is a strongly bleached clay (Plate II, 1) coming in the category of a peaty gley. Numerous fine root traces are seen in the upper horizon, but these peter out at about 12 in., where the clay becomes solid.

The A/T profile shows that the 4 in. of forest humus overlying the flint zone is devoid of iron, but that above this the character of the humus changes markedly, showing a strong iron colour on ignition.

Site No. XXXII. WINTER HILL BARROW

Place

Near the summit of Winter Hill, 5 miles NW. of Bolton, Lancs.

National grid reference

SD/658149.

Geology

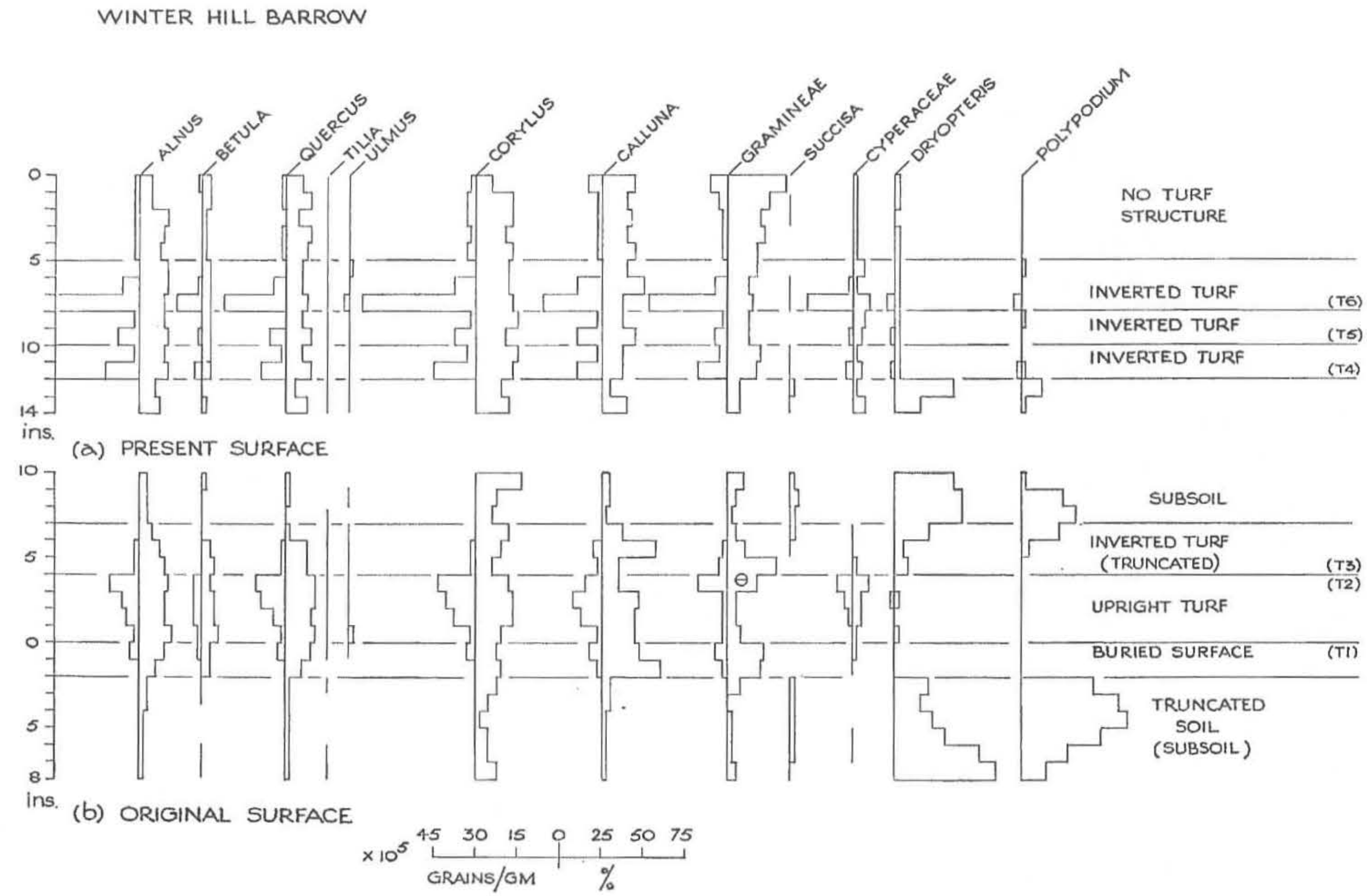
The barrow was constructed on mineral soil derived from the Millstone Grit of the Carboniferous, but is now partially covered by peat.

Topography

200 yds. from the summit of an isolated hill, on a west-facing slope. Altitude 1,460 ft. O.D.

General

The site was investigated at the request of archaeologists, but produced useful data about high-altitude conditions in the Bronze Age. The barrow was constructed of turves.


WINTER HILL BARROW
ALNUS
BETULA
QUERCUS
TILIA
ULMUS
CORYLUS
CALLUNA
GRAMINEAE
SUCCISA
CYPERACEAE
DRYOPTERIS
POLYPODIUM
0
5
10
14
ins.
NO TURF STRUCTURE
INVERTED TURF (T6)
INVERTED TURF (T5)
INVERTED TURF (T4)
(a) PRESENT SURFACE
10
5
0
5
8
ins.
SUBSOIL
INVERTED TURF (TRUNCATED) (T3)
(T2)
UPRIGHT TURF
BURIED SURFACE (T1)
TRUNCATED SOIL (SUBSOIL)
(b) ORIGINAL SURFACE
x 10^5 45 30 15 0 25 50 75
GRAINS/GM %

Pollen analysis

Two series of samples were taken, one from the present surface down into the turf structure, and the other from the turf structure into the subsoil of the buried soil.

The top five samples of the upper series were unstratified and probably consisted of a mixture of mineral and organic layers from a soil contemporary with the barrow. This material contains a moderate amount of inherent pollen (old types such as *Alnus*, *Corylus*, *Quercus*, *Tilia*, and *Ulmus*). In addition, the grasses and *Calluna* fractions probably contain some ancient pollen, but it is significant that these two groups alone show increased frequency at the surface. There is no parallel increase in Cyperaceae pollen.

The upper series passes through three turves (T4, 5, and 6), each of which is inverted. They show very similar tree-pollen spectra and NTP percentage values; these are described below.

The lower series of samples ran through one complete and upright turf (T2), an inverted and truncated turf (T3), and the humus line which in the field was taken as the buried surface of the soil, here used as a datum line. The complete turf showed in its surface (T2) a spectrum almost precisely the same as those of the turves in the upper series. The humus line beneath the barrow, however, gave a somewhat different spectrum. These are shown in the following table:

Turf	*Alnus*	*Betula*	*Fraxinus*	*Pinus*	*Quercus*	*Tilia*	*Ulmus*	*Corylus*	*NTP*	*ΣTP*
T6 .	45·6	13·1	2·5	0·6	35·6	0·6	1·9	64·4	108·8	160
T5 .	45·8	12·0	..	1·2	40·0	2·4	0·6	44·6	103·0	166
T4 .	47·6	10·7	1·3	0·3	38·9	1·3	+	64·3	99·4	319
T2 .	42·2	10·2	1·8	+	41·6	1·8	2·4	49·4	95·2	166
Mean	45·7	11·3	1·4	0·5	38·6	1·5	1·0	57·2	101·1	811
T1 .	37·7	14·9	2·2	0·7	41·8	1·1	1·5	38·1	137·7	268

It seems quite clear that T1 represents more open conditions than the turves, suggesting that the barrow was built in a treeless clearing, whereas the turves came from open woodland or glades. The conclusion that the turves came from some distance away is confirmed by the fact that T1 shows a sharp unconformity at 2 in. with the soil beneath, suggesting that it has formed on a truncated soil, whereas the turves (e.g. T2) show no such unconformity, but rather the gradual transition down the profile which is normal.

As at the Burton Howes (Sites VI and VII) the turf analyses show a predominance of *Quercus* and *Alnus* pollen and a rather similar relationship between forest and open country. Another close parallel is the lack of evidence of cultivation; these high-level Bronze Age sites show remarkable parallelism.

Soil characteristics

The soil beneath the barrow was an incompletely developed thin iron-pan podzol, with an iron-pan forming at a very variable depth, but averaging about 8 in. (Plate III, 3). The turves of the mound vary a good deal in their iron content and are somewhat difficult to interpret. Those nearer the surface of the barrow are more completely leached; in fact some of them, e.g. T4 and T5, show more intensive leaching of the attached mineral soil than does the buried soil. This may be related to the fact that the upper layers of the buried soil appear from the pollen analyses to have been truncated. Whether this was an artificial or natural process it is impossible to say.

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PLATES

I. 1. Humus–iron podzol exposed in sandpit. Note the root-like projections of the leached layer into the subsoil. Current-bedded Folkestone Sands, Oakhanger, Hants.

2. Calcareous gravel in the valley of the River Kennet, Thatcham, Berks., showing iron deposition near the water table.

3. Gully erosion along tracks off the moor. Biller Howe Rigg, North Riding, Yorks.

4. Extensive moorland erosion at Cock Heads on the Cleveland Hills. Soil—a peaty-gley.

II. 1. Mesolithic flints *in situ* below humus layer. White Gill, Stony Rigg, Cleveland Hills.

2. Mesolithic flints in humus–iron podzol. Oakhanger—The Warren.

3. Decoy Heath, Wareham, Dorset.

4. Keston Common, Kent. Possibly a 'double' soil.

III. 1. Bickley Moor Barrow—modern and buried soils. See Plate IV. 1.

2. Chick's Hill Barrow—buried soil.

3. Winter Hill Barrow—turf structure and buried soil.

4. Burton Howes Barrow 4 D. Buried soil and turf structure showing also the secondary extension of the mound.

IV. 1. A/T profile of Bickley Moor Barrow. See Plate III. 1.

2. A/T profile of Springwood Barrow, showing modern and buried soils.

3. A/T profile of buried soil under Springwood Barrow. More intensively leached than in 2.

4. A/T profile of buried soil under Reasty Top Barrow. The buried level is marked by the dotted line.

V. 1. Thin iron-pan soil under the turf mound of Burton Howes Barrow 1A.

2. Thin iron-pan soil, Suffield Moor—Heath. See Plate VI. 1.

3. Regenerating thin iron-pan soil. Suffield Moor—Birch. See Plate VI. 2.

4. Thin iron-pan soil, unchanged under old Scots Pine. Suffield Moor—Pine.

VI. 1. A/T profile of Suffield Moor—Heath. See Plate V. 2.

2. A/T profile of Suffield Moor—Birch, showing redistribution of iron in A_2 horizon. The dotted line marks the buried level. See Plate V. 3.

3. A/T profile of an acid brown forest soil. Burley Oak.

4. A/T profile of Pondhead, showing the iron coloration associated with the mull layer. The dotted line marks the buried level. See Plate VIII. 4.

VII. 1. A slightly degraded acid brown forest soil on Plateau Gravel. Matley Wood.

2. Humus–iron podzol associated with deciduous forest; buried beneath Iron-Age rampart, Keston Camp.

3. Immature podzol beneath Late Bronze Age barrow—Burley Barrow. The holes in the face were caused by rabbits. Compare with 4.

4. Burley Heath. Present-day heath podzol, a few yards away from 3.

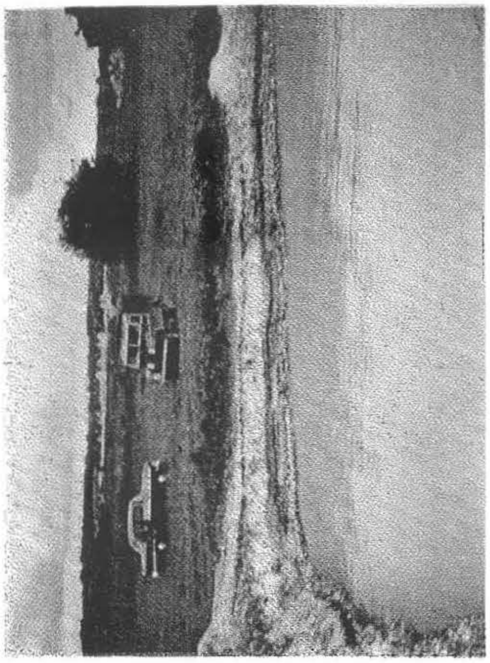
VIII. 1. and 2. Variants of the heath podzol of Lyndhurst—White Moor.

2. Lyndhurst—The Ridge. Buried soil beneath medieval earthwork. Compare with 1 and 2.

4. Pondhead. Compare with other profiles on this plate, all in the same area. See Plate VI. 4.

PLATE I

1



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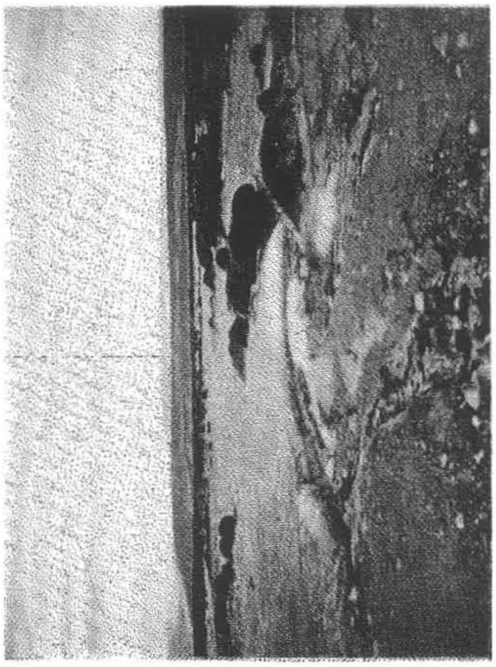

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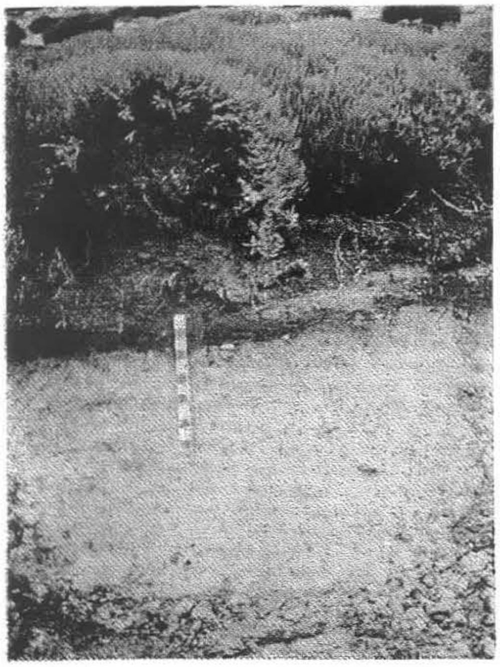

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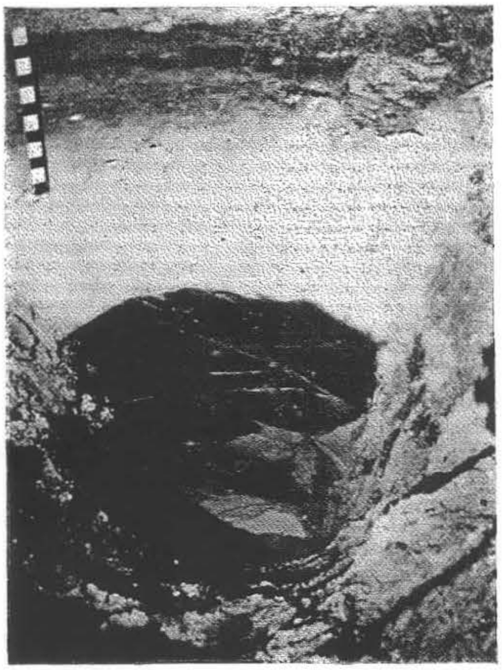

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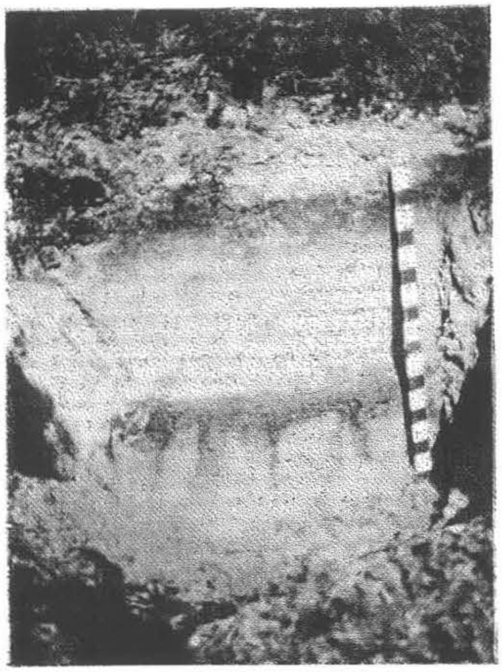

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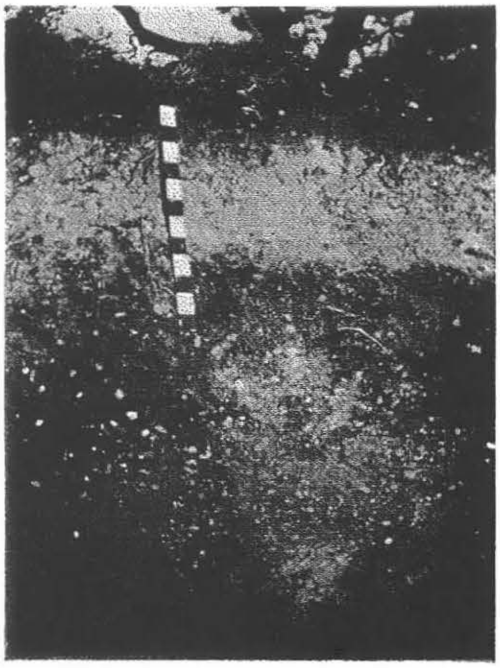

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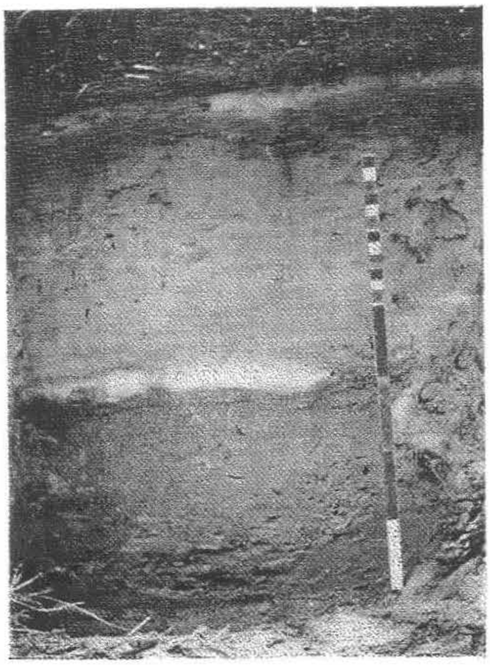
PLATE III



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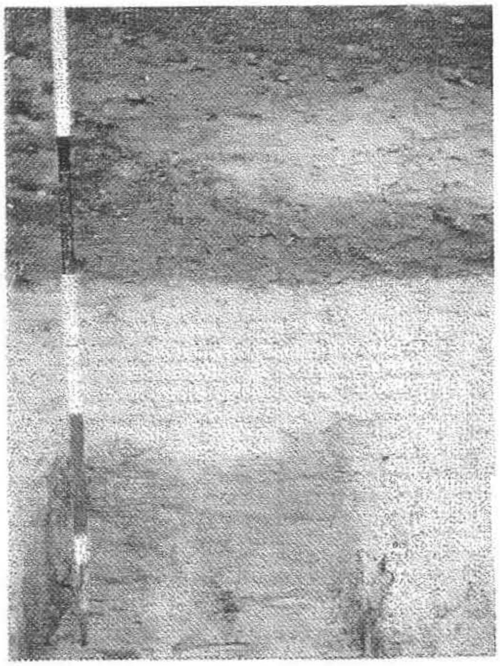

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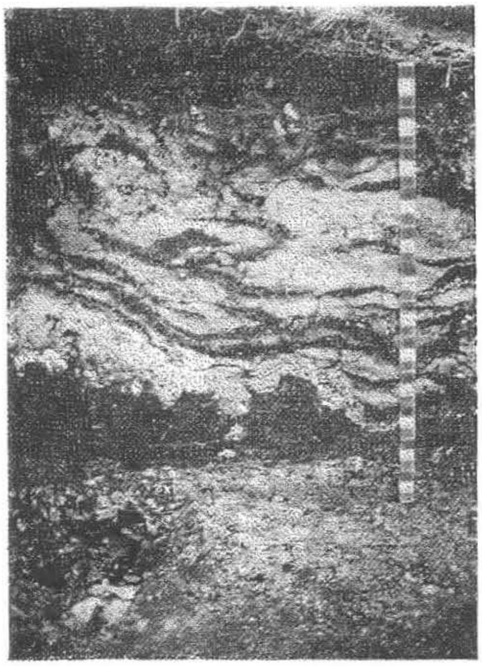

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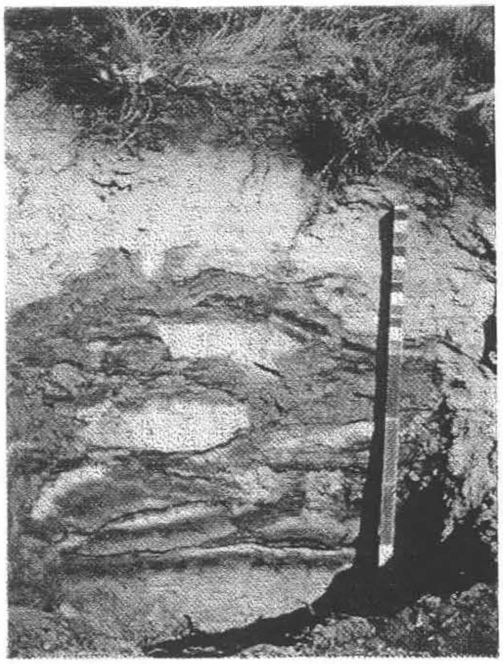

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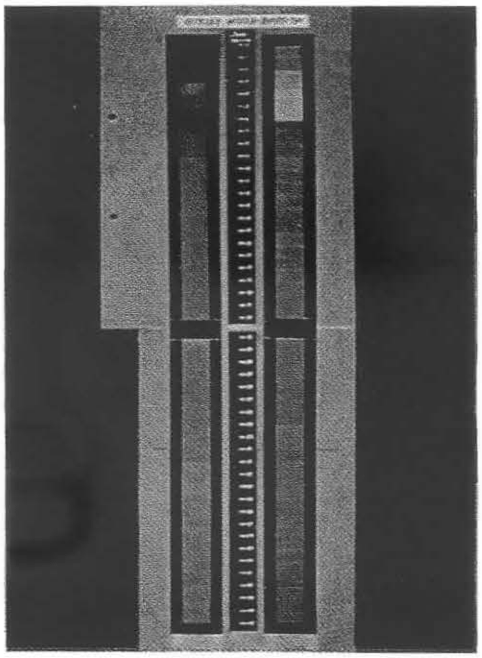

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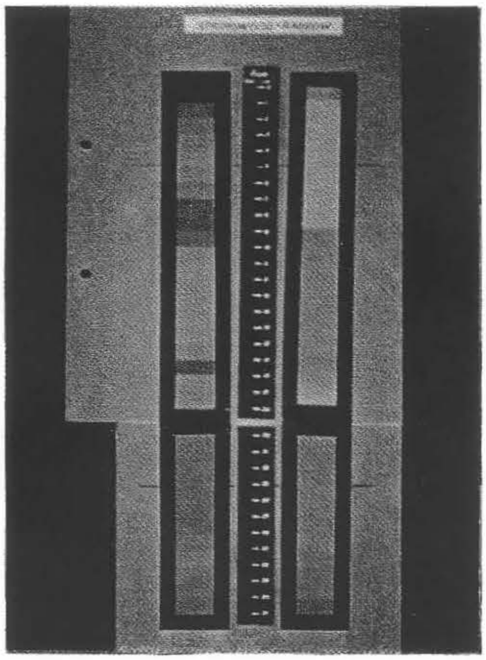

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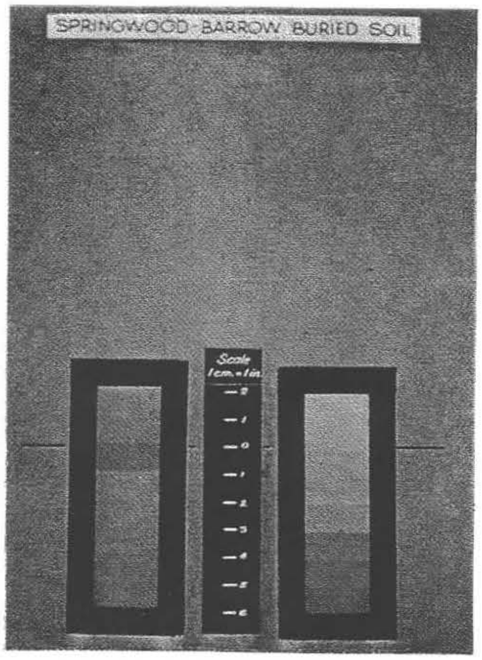
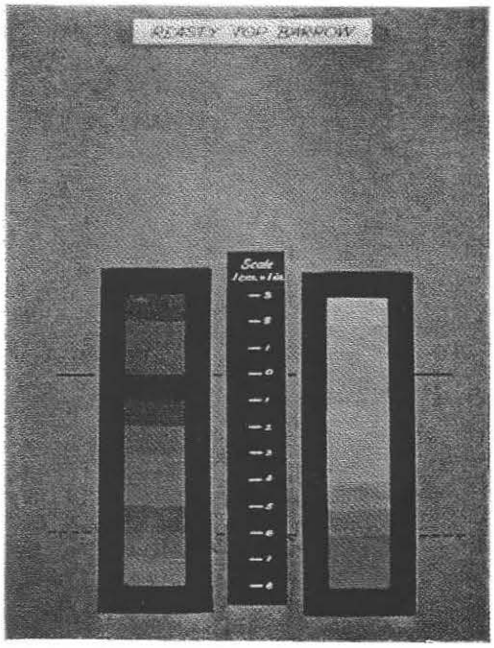

SPRINGWOOD BARROW BURIED SOIL
Scale
1 cm. = 1 in.

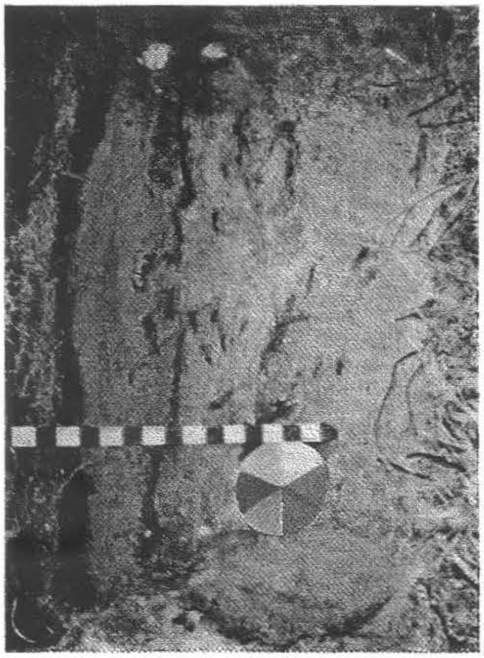
3


BARROW
Scale
1 cm. = 1 in.

4

PLATE V

1



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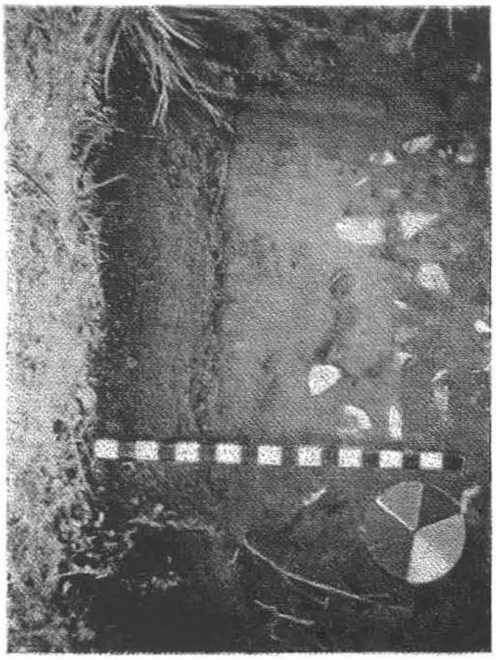

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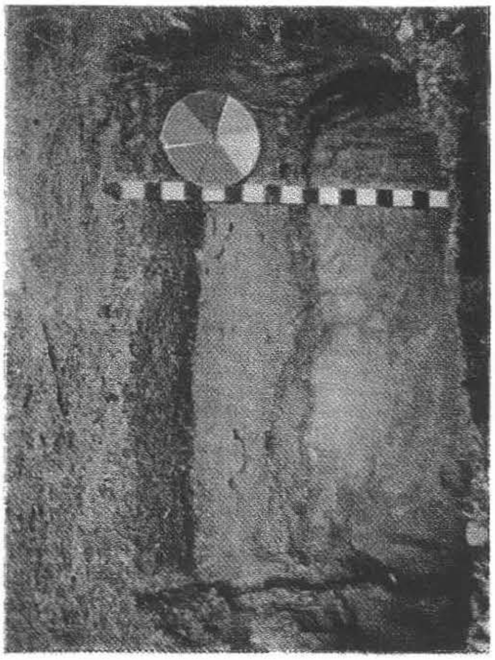

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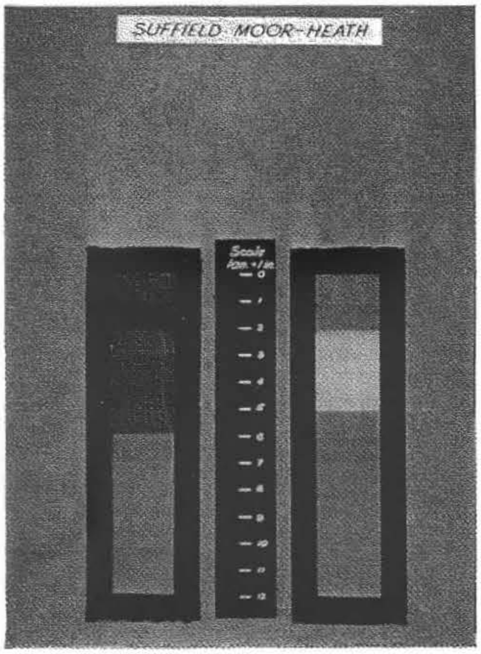
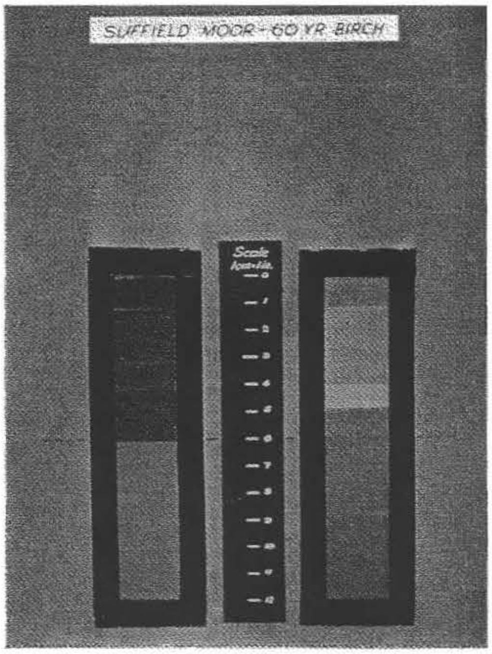
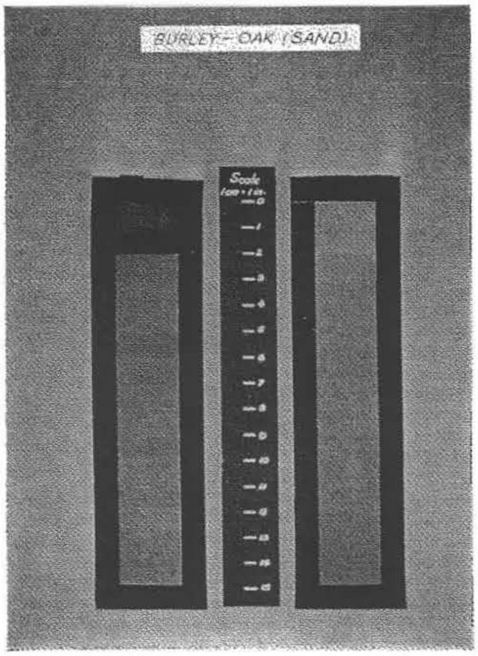

SUFFIELD MOOR–HEATH
Scale

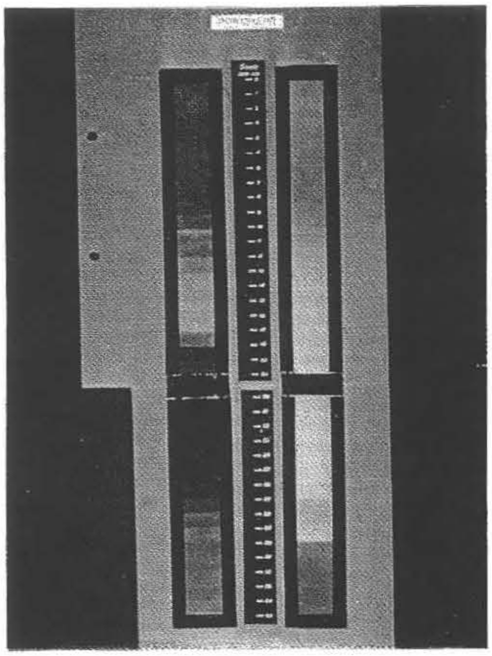
1


SUFFIELD MOOR–60 YR BIRCH
Scale

2


BURLEY–OAK (SAND)
Scale

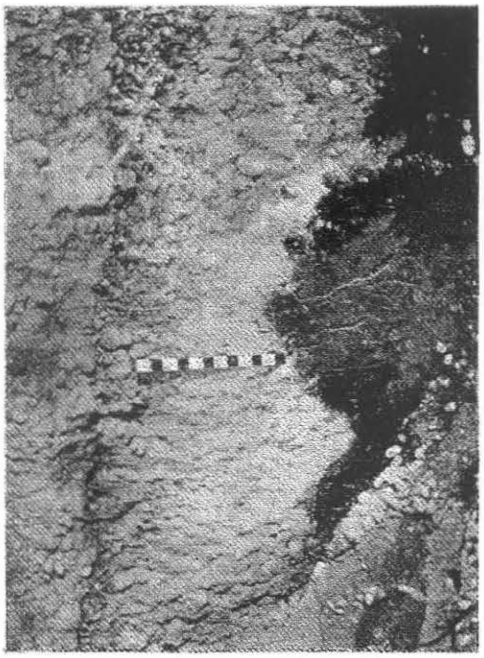
3



4

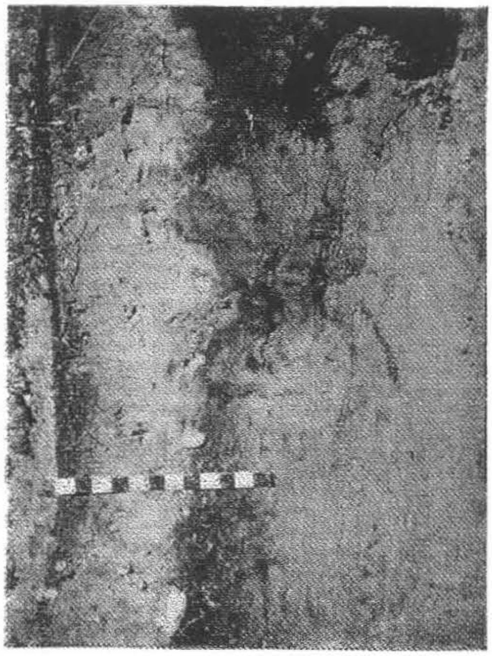
PLATE VII

1



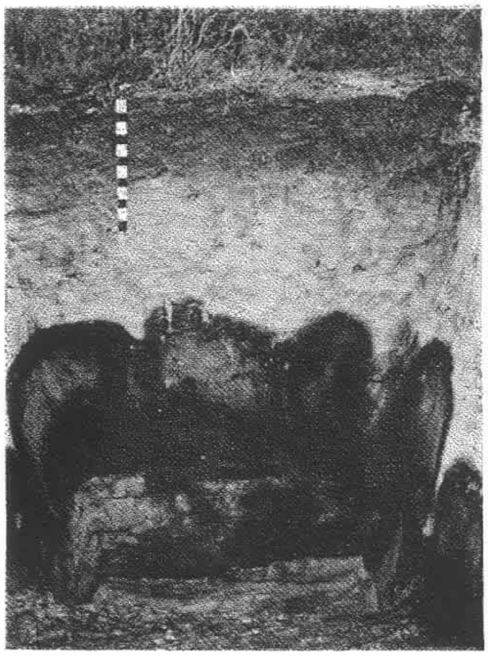
2

3



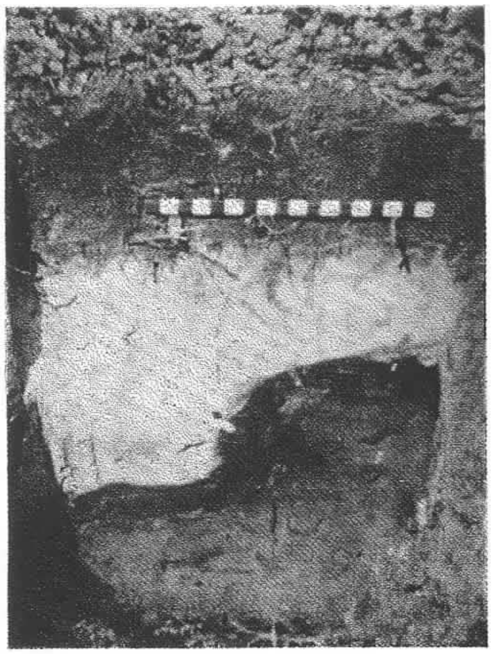
4

1



2

3



4